Technical Bulletin No. 8

STUDIES ON THE MECHANISM OF PREVALENCE OF THE RICE BLAST DISEASE IN THE TROPICS

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Yoshio HASHIOKA

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FOREWORD

The rice blast disease has long been a very serious problem for rice production in Taiwan and elsewhere. Many a phytopathologists have endeavoured to attack this problem, but their works were mainly restricted to the conditions prevailing in temperate zone. Mr. Y. Hashioka, formerly phytopathologist of our Institute, has made a comprehensive study of this subject for more than 10 years in this island. Some of his preliminary reports appeared in several Japanese journals which are not easily accessible. The present volume is a summary of his researches which has contributed much to the advancement of our knowledge in this horrible disease and constitute the basic data for its control. The manuscript was ready in June 1948. But its publication has been long delayed because of the financial difficulties of our Institute.

On behalf of the Institute, I have much pleasure to acknowledge our indebtedness to the Joint Commission on Rural Reconstruction for financing the publication of this report.

Taipeh, Taiwan
January 1950.

W. T. Tang, Director

STUDIES ON THE MECHANISM OF PREVALENCE OF THE RICE BLAST DISEASE IN THE TROPICS

Yoshio HASIOKA

INTRODUCTION

It is worthy of special mention in the history of control of plant diseases that the method of control of the rice blast disease proposed by Ito and his co-workers (1932, *et passim*), based upon their extensive studies on the relation of viability of the rice blast fungus to the environmental conditions, has proved to be very efficacious for the prevention of that disease in the northern districts of Japan. However, the experiments concerning the application of the above-mentioned treatment under the subtropical conditions conduated consecutively from 1939 to 1941 at seven agricultural experiment stations in Formosa failed to achieve satisfactory results. Moreover, the result of the treatment to the paddy field applied by the farmers of the same island under compulsion was almost the same as in the case of the above experiments. Such a contradiction of these results in these two districts is considered to be attributed to the difference of the phenomena effected by the difference of the environmental conditions, and neither due to the irrationality of Ito's theory for to the ill-management made by the farmers in this south island. It goes without saying that the cultural conditions in two districts are very different in many respects, viz. host-parasite relation in the temperate and tropical environments, methods of cultivation, and the varieties of rice plants raised in these two regions, etc. Therefore, in order to find a new method suitable for the subtropical and tropical environments, further consideration regarding the matter, particularly in the tropics, must be made. From the above-mentioned point of view, the author attempted to find out the fundamental principle on the method of control of the rice blast disease in the tropics by studying the fol-

lowing points, namely, firstly clarifying the factors constituting the prevalence of the disease by studying the relations between the environmental conditions and the mode of prevalence in both the temperate and tropical regions, secondly making clear whether or not those factors found by the above-named studies are actually connected with the prevalence in nature, and finally detecting the differences of the mode or mechanism of prevalence between the temperate and tropical regions. From the results of the above-named studies, the author accomplished his purpose mentioned above by clarifying the characteristics of the rice blast disease in the tropics. This paper deals with the results of the experiments conducted chiefly at Taichung Agricultural Experiment Station at Taichung (Taichu) from 1937 to 1946 and partly at Taiwan Agricultural Research Institute at Taipeh (Taihoku) in 1947. It is a pleasure of the author if this work could contribute something not only to the field of control of the rice blast disease in the tropics, but also the to so-called tropical phytopathology which is expected to develop into a new science in near future.

Before going further, the author desires to acknowledge his indebtedness to Dr. Matsumoto, ex-Prof. of Taihoku Imperial University, for his valuable suggestions and criticisms in connection with this work as well as as preparation of this paper. Thanks are also due to Dr. E. Iso, ex-Prof of the same university and ex-Director of Agricultural Research Institute of Government of Formosa, who kindly encouraged the author throughout this study, and Dr. S. Hayashi and other gentlemen, ex-members of Taichung Agricultural Experiment Station, who kindly helped the author in various ways throughout the course of this study. During his stay in Taiwan Agricultural Research Institute, the author is greatly indebted to Director L. Ling, Acting Director W. T. Tang, and Mr. C. H. Hung and other staffs of the phytopathological department, for the facilities for this work as well as publication of this paper. Furthermore, a part of the expense of this investigation has been defrayed by the Society for Promotion of Scientific Research of Japan, for which the author expresses his sincere thanks.

CHAPTER I

MATERIALS AND METHODS

In this chapter the materials and methods commonly employed throughout the experiments are only described, and the others used for the special purposes will be mentioned later in the respective chapters and sections.

The Varieties Used

The variety 'Taichu No.65', the hybrid between the Japanese varieties, 'Kameji' and 'Shinriki', was employed throughout the experiments unless otherwise mentioned, but many others were also used for comparison. Especially in the experiments on the varietal resistance about 400 varieties endemic to the various districts in various latitudes covering the whole Asia were employed.

Cultivation of the Employed Plants

In the experiments concerning the disease of leaves, 10 to 30 seedlings were cultured in a glass cylinders of 1/1,000,000 ha. or in a porcelain pots of 1/200,000 ha. filled with soils containing fertilizers of twice as much as the ordinary amounts in the paddy field, viz., 200 kg. of ammonium sulphate (N 20.5%), 600 kg. of calcium perphosphate (P_2O_5 19.0%), 200 kg. of potassium sulphate (K_2O 48.0%) per ha. unless otherwise mentioned. They were kept in the glass house under controlled conditions, comprising those of sunlight, temperature of air and soil, fertilizers, etc, and used for inoculation, when they attained the early stage of tillering. In the experiments of the disease of the ear, the plants were cultured in the same manners as in the case of the above-mentioned, excepting that the number of plants in each pots (1/200,000 porcelain pots) were three, and they were inoculated on the ear or on the neck of ear. Furthermore, experiments were often conducted in the paddy field with the plants cultured by the ordinary

way, nitrogenous fertilizer being given twice, triple or quadruple as much as in the ordinary paddy field.

Inoculation

Under Formosan conditions the conidia of the rice blast fungus are feeble in pathogenicity when they are grown on any kinds of artificial culture media, even on those of the rice straws, so far as the author's experiments are concerned. For the reason stated above, fresh conidia were always provided as inoculum by means of culturing the blast fungus successively on seedlings or rice plants in the glass house. A special care was taken to minimize the chance of intruding extraneous strains of the fungus in question. Less frequently, however, the conidia naturally born on leaves or on the neck of ear in the paddy field were also used as inoculum when the above-named cultured spores were not sufficient enough for the experiments. In this connection, it is to be remembered that the spore suspension prepared from the field born conidia usually contains a comparatively large amount of conidia of *Fusarium* spp., a small number of those of *Helminthosporium* spp. (mostly *Ophiobolus Miyabeanus*), and other miscellaneous fungi. Aoki (1937) reported that germination of conidia of *Piricularia oryzae* is diminished to a certain extent when the former were sown together with the conidia of *O. Miyabeanus*. Ikeya (1934) and Hemmi *et al.* (1936) also pointed out that the pathogenicity of *P. oryzae* was weakened when this was inoculated with *O. Miyabeanus*, but was rather invigorated in association with *Fusaria*.※ Considering the facts mentioned above, use of the conidia collected from the field was only allowed when the cultured inocula were deficient in quantity.

Inoculation was made by spraying the above-named spore suspension on the plants under the circumstances of desired ages and conditions. The inoculated plants were kept in the constant temperature infection chamber regulated at 28°C under saturated humidity without illumination. After

※More recently, Andersen et al. (1947) stated that, in some cases, the development of P. oryzae on the host was reduced by the presence of O. Miyabeanus, though on the agar media or in water they could observe no antagonism between these two fungi.

24 hours they were removed from the chamber and arranged on the bench in the glass-house until the disease appeared. When the environmental conditions were not suitable for outbreak of the disease, or when the special care had to be taken to avoid the natural infection, they were kept in a small glass chamber placed in the glass-house in which temperature and humidity were more favourable for the outbreak of the disease than in the ordinary glass-house.

Determination of the Grade of Infection and Comparison of the Physiologcial Properties of the Plants Used

The grade of infection was determined by counting the number of lesions on each plants or per unit length of the leaves, by measuring the length and width of the lesions, by deciding the colour of the lesions, and by comparing sporulation, etc. Comparison of the morphological, anatomical, physiological and phytochemical properties of the plants was conducted by use of various means which will be mentioned later in respective chapters. Quantitative analysis of the chemical substances was conducted by the following methods, *i.e.*, the total content of nitrogen - Kjeldahl method; content of potash - Ohsugi-kawai's method (modified Wikul's method). The grade of silicification in epidermal cells of the leaves was determined by counting the number of silicated epidermal cells, including silicated motor cells, silicated long and short cells, and silicated stomatal cells, per unit area (an optical field of Winkel 3 X 7a), after treated with phenol as has already been tried by Crob (1896) and Suzuki (1933, *et passim*).

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CHAPTER II

ANALYSIS OF THE TROPICAL ENVIRONMENTS IN RELATION TO THE RICE-CROP, WITH SPECIAL REFERENCE TO THE PREVALENCE OF THE RICE BLAST DISEASE

Section 1. Macro-climate

A. Temperature

Inducing from the results of the experiments mentioned in chapter III and IV, the temperature range of growth of the rice plant and rice blast fungus is considered as follows:

Table 1. The temperature range of growth of the rice plant and blast fungus.

Host or parasite	Minimum (°C)	Optimum (°C)	Maximum (°C)
Rice plant	7 - 8(13 - 14) ※	28 - 32	40※
Blast fungus	7 - 8	26 - 28	34 - 36

※Water temperature

As shown by the above table, temperature range of growth of both the host and parasite is almost alike, though the latter is somewhat lower in the optimum and maximum than the former. The minimum temperature permitting the active growth of the host and parasite in nature, such as, elongation of leaves and stems, tillering, etc., in the former and germination of conidia, intrusion into host tissues, etc., in the latter, is approximately 15°C, being somewhat higher than the minimum which was determined by the laboratory experiments as shown in table 1. Furthermore, favourable growth of both is regarded to require the temperature higher than 20°C. In consideration of the facts mentioned above, cultivation of rice plants in Eastern Asia can be divided into the following

four types.

(1) Temperate type

One crop is hardly raised throughout the year. For instance, in the northern part of Japan and North China which are surrounded by the isothermal lines ranging from 5 to 10°C in the average of the whole year (vid. fig. 1), temperature is mostly under 15°C all the year round, so that rice plants can not grow normally in such a low temperature condition.

(2) Subtemperate type

In the southern half of Japan. Middle China, etc. where the isothermal lines lie between 10 and 20°C on the average (mostly higher than 15°C), rice plants grow satisfactorily escaping the damage from the cold, though the crop is once a year.

(3) Subtropical type

Two crops are raised regularly every year as in the case of Formosa, South China, the northern part of Indo-China Peninsula and the northern India, where the temperature of the most part of the year is higher than 20°C, ranging from 20 to 25°C in isothermal lines.

(4) Tropical type

This type is characterized by the fact that the rice plant is raised rather irregularly throughout the year, as will be seen in the tropical Asia, including many South Sea islands, the southern part of Indo-China Peninsula, southern India, etc. which are mostly passing along the isothermal line of 25°C, and warmer than 20°C all the year round.

The rice plants of the first type are frequently affected not only by the physiological disturbance, but also by reduction of resistance to the blast disease (vid. chapt. IV), since the temperature is lower than the optimum for the growth of the plant even in the warmest season of the year, while those of the second type are mostly free from them except in the seedling stage. In these two districts the blast fungus must be exposed to the cold for a considerable length of period either in the dead host tissue or apart from it. In the case of the third type, the seedlings of the plants in the lst crop are frequently affected by decrease of temperature below 15°C, while in the second crop the temperature of the seedling

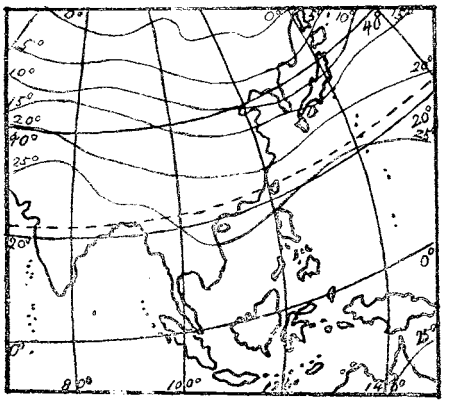


Fig. 1. The isothermal lines of the yearly average temperature in Eastern Asia.

stage is much higher than the above, almost approaching to the maximum for growth. In this region, therefore, the 1st crop is raised towards the ascending degree of temperature, but in the 2nd one the temperature relation is quite opposite to that of the former, and the temperature during the vegetative period of the 1st crop of the subtropical type is higher than that of the temperate type, particularly in higher latitudes, though lower than that of the subtemperate type, while in the 2nd crop the temperature is the highest of all the types mentioned above. Moreover, the difference of temperature during the vegetative growth between the 1st and the 2nd crop is 5-15°C, consequently, these two crops are exposed to the temperature of minimum and maximum for growth, respectively. For example, the temperature range during all the growth period of variety 'Taichu No. 65' raised in Taichung (24°09'N) is shown in table 2 and fig. 2.

Table 2. Average temperature during the growth period of variety Taichu No. 65' raised in Taichung.

Crop	Period & temp.	Seedling	Tillering	Booting-heading	Maturity
1	Period	20 / I - 19 / II	20 / II - 4 / IV	5 / IV - 21 / V	22 / V-3 / VI
	Temp.°C※	16.2	19.0	23.7	26.5
2	Period	5 / VII-24 / VII	25 / VII-24 / VIII	25 / VIII-7 / X	8 / X - 27 / X
	Temp.°C※	27.5	27.8	27.3	23.7

※ Mean of 5 years from 1939 to 1943.

Such a great difference of temperature between these two crops causes the difference of prevalence by exerting influence upon the growth of the parasite and also upon the resistance of the host, as will be mentioned in

chapter III and IV. In the last-named type, no apparent difference in temperature condition as well as in host resistance is noticed all the year round, moreover, the blast fungus can survive on the living hosts throughout the all seasons owing to the constant higher temperature.

B. Humidity

Humidity during the growing period of rice plants is about 80 per cent of relative humidity everywhere in the Eastern Asia regardless of the difference of the latitude and geographical features with the exception that in the rainy season of the temperate, subtemperate and subtropical region it goes up to 83 per cent or more. As regards the subtropical type, humidity is generally higher in the lst crop than in the 2nd crop, but the difference between these two crops is only about 5 per cent. In consideration of the facts mentioned above as well as by the reason that the resistance of the rice plants is not much influenced by air humidity as will be stated later in chapt. IV.

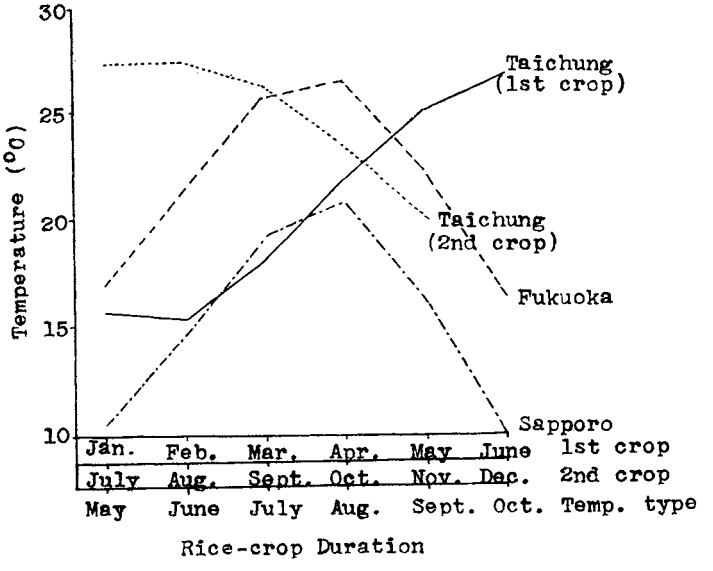


Fig. 2. An antithesis of the temperature of monthly average during cultivation of the rice-crop in the temperate-and tropical regions.

humidity may not be so important as a controlling factor for the prevalence of the disease, although up to this time we have attached too much importance to this factor.

C. Solar Radiation

The length of daytime during the younger stage of rice plants in the region of the northern limit of the rice-crop is about 15 hours which is longest among all the types of rice cultivation. On the other hand, the shortest of it is seen in the similar stage of the lst crop in the subtropical type, of which length is only 11 - 12 hours. Consequently, the difference between them amounts to 4 hours. In the subtropical type, the lst crop grows towards the increase of the length of day-time, while the 2nd one towards the decrease of it. For instance, in Taichung (24° 09'N), the length of day-time is from 11 to 13.5 hours in the first crop, and in the latter it is from 13.5 to 11.5 hours. Moreover, it is one hour shorter in the former and 1.5 hours longer in the latter as compared with that in the tropics where the day length is almost uniform throughout the year. The duration of sunshine in the rice-crop regions is rather dependent on the weather conditions than on the latitude. But, on the whole, in the case of the subtropical type it is shorter in the lst crop and longer in the 2nd crop in comparison with that of the temperate type. Furthermore, difference of sunshine duration during the vegetative growth of the rice plants between the lst crop (3.0-5.5h.) and the 2nd crop (7.5-8.0 h.) amounts to 2.5-4.5 hours. Insolation (solar radiation) during the cultivation of rice-crop is in intimate relation to the length of day. That is to say, it is larger in the temperate type than in the subtropical or tropical type. Insolation of the lst crop of the subtropical type is the smallest among that of all the types on account of shortness of day length and heavy cloudiness.

Among the various factors of sunlight mentioned above, length of day-time and insolation are important for the prevalence of the disease by the reason that these factors have influence upon the resistance-susceptibility relations of the host plants owing to their effect on

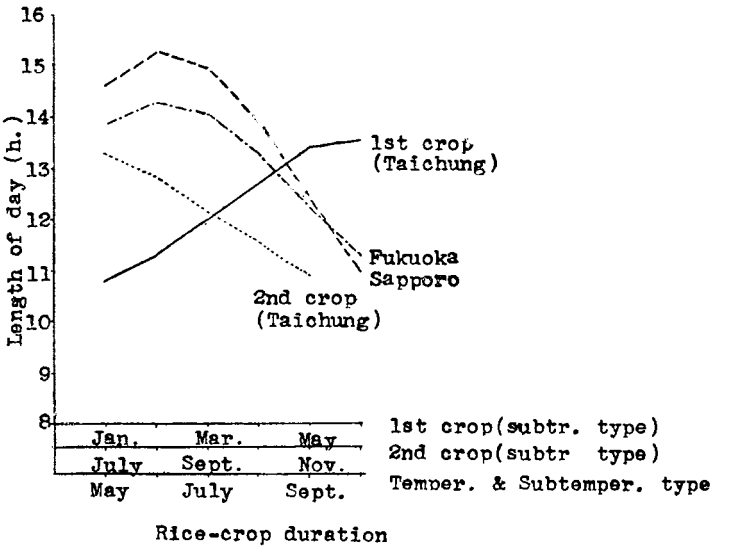


Fig. 3. An antithesis of the length of day-time during cultivation of the rice-crop in the temperate-and tropical regions.

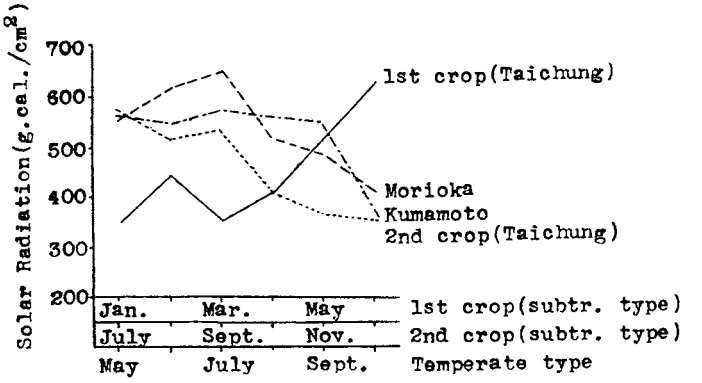


Fig. 4. An antithesis of amount of insolation during cultivation of the rice-crop in the temperate-and tropical regions.

photosynthesis, especially the former correlates with escaping of ears from blast disease because of its effect upon the length of the vegetative and reproductive stage of the plants.

From the facts mentioned above, it is concluded that temperature is

most important among the environmental factors for the prevalence of the blast disease. The temperature during the vegetative growth of the plants is lowest in the temperate type, followed by the lst crop of the subtropical type, the subtemperate type, the tropical type, the 2nd crop of the subtropical type, in the order named. It must be remembered that in the lower temperature the rice plants are not only reduced in growth but also diminished in resistance to the disease, though the causal fungus is also more or less effected by coldness, while in the higher temperatures the result is quite contrary. On the basis of the length of day and insolation in relation to the vegetative growth of the plants, the above-named types can be arranged as follows: The temperate type>the subtemperate type >the 2nd crop of the subtropical type >the tropical type >the lst crop of the subtropical type. Although the length of day and insolation is more important for the outbreak of the disease than the other factors of sunlight, they are of less importance in nature as compared with a temperature factor, since they can not control the prevalence, so far as the extent of change taking place in nature is concerned, notwithstanding their influence upon the host-parasite relations is very conspicuous as will be mentioned later in chapt.IV.

Section 2. The Microclimate of the Paddy Field of The First and the Second Crop in the Subtropical Regions In Relation to the Prevalence of the Blast Disease of the Leaves

As regards the microclimates of the paddy field, there are some studies, such as those Matsuno *et al.* (1937) and Suzuki *et al*. .(1943), etc., but the studies with special reference to the prevalence of the present disease are extremely limited except for some observations on the conidial dissemination (Kuribayashi *et al.*,1941; Yamagata Agr. Expt. Sta.,1942). Accordingly, the microclimate of the paddy fields was observed in order to confirm whether or not it is different from the macroclimate of them,

and further to know whether or not it is related to prevalence of the blast disease. Observation was conducted at the field of Taichung Agricultural Experiment Station (situated at 24° 09'N) in 1943. The plot used for the observation is 10 are in area, planted with the variety 'Taichu Sp. No. 6' (A selection from the Japanese variety 'Asahi') at the distance of 20 X 25 cm., and constantly irrigated with running water at the depth of about 5 cm. Observation was made in the lst-and 2nd crop, 60 and 37 days after transplanting, respectively. In these stages of growth the plants were about 60 cm. in height, shortly before the culmination of tillering, and slightly susceptible to the blast disease. Air temperature, air humidity, wind velocity and intensity of light were observed at each of the following layers: The layer of the atmosphere, 100 cm. distant from the surface of irrigation water (namely at the height of 40 cm. from the top of the plants); the upper layer of the space occupied by the plants, 50 cm. from the surface of irrigation water, where the leaves of the plants are not much crowded; the middle layer of the space occupied by the plants, 30 cm. from the water surface which is densely crowded with leaves; the lower layer of the space occupied by the plants, 10 cm. from the water surface which is rather thinly covered with leaves. Water temperature was observed at the point of 2.5 cm. above the ground, and soil temperature was recorded at the depth of 5, 10, 20 and 30 cm. respectively, The instruments used for the measurements are as follows:

Insolation - a Robitzch self-recording actinograph (unit g.cal.cm2/h.).

Intensity of illumination-Matsuda illuminometers (unit lux).

Temperature and humidity of air - Assman's aspirating thermometers (unit °C & %).

Water temperature - Ordinary rod-shaped thermometers (unit °C).

Soil temperature - Earth thermometers (unit °C).

Wind velocity - Birum's anemometers (unit M/sec. used together with wind-vanes made with thick papers).

Amount of evaporation - The circular filter papers of certain weight moistened with distilled water (indicated by percentage of decrease of weight after 20 minutes of hanging at the desired layers.).

All the instruments used in the measurement of the air layers were hanged with the cords so that their sensible parts are suspended at the certain height by use of pullies prepared on a girder of 2 meter high.

A. Micro-temperature

(a) Hourly change of air temperature in the paddy field

As will be seen in figs. 5 and 6, in the fine weather, air temperature of the above-mentioned paddy plot ascends to almost 30°C in the day-time and decends to about 20°C at night, showing the extent of change of about10°C in the 1st crop, but in the 2nd crop it usually showes about 32°C, 25°C and 5°C, respectively. Namely, between the 1st- and the 2nd crop, there are distinct differences not only in warmness but also in the range of daily change.

(b) Differences of temperature between the atmosphere and plant--layers

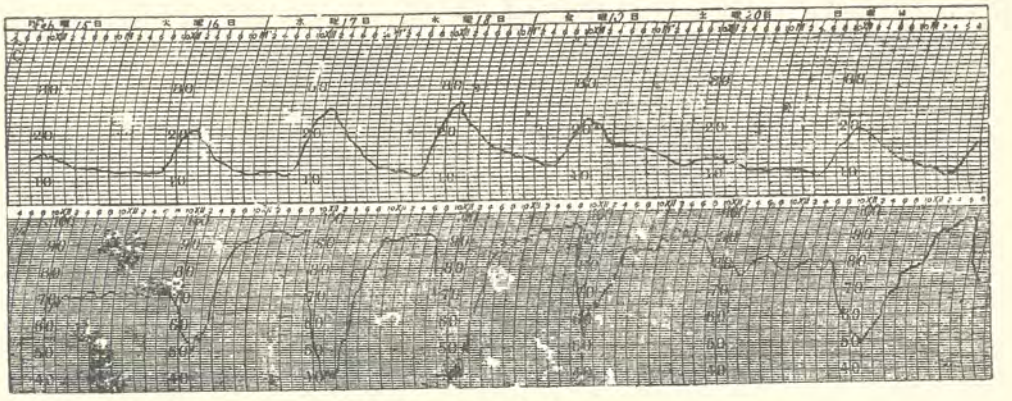
The temperature of the plant-layers changes in almost parallel with that of the atmosphere, although the former is usually more or less cooler than the latter, as shown in the following table and fig.6.

Table 3. Difference of temperature between the atmosphere and the middle part of the plant-layer during the time of ascending of temperature in the forenoon.

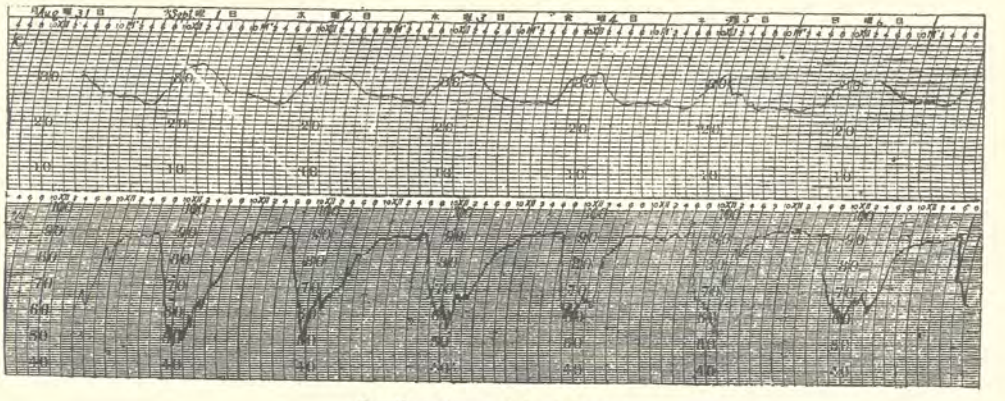
Crop	Date	Time (O'cl.a.m.)	Air temperature °C		
			Atmosphere	Middle plant-layer	Diff. of the latter in comp'n with the former
1	Apr.22	9	26.2	24.8	-1.4
		10	28.0	25.2	-2.8
2	Sept.4	9	29.8	28.0	-1.8
		10	30.8	29.6	-1.2

(c) Relation between the temperatures of the atmosphere and soil as well as between those of the air and water

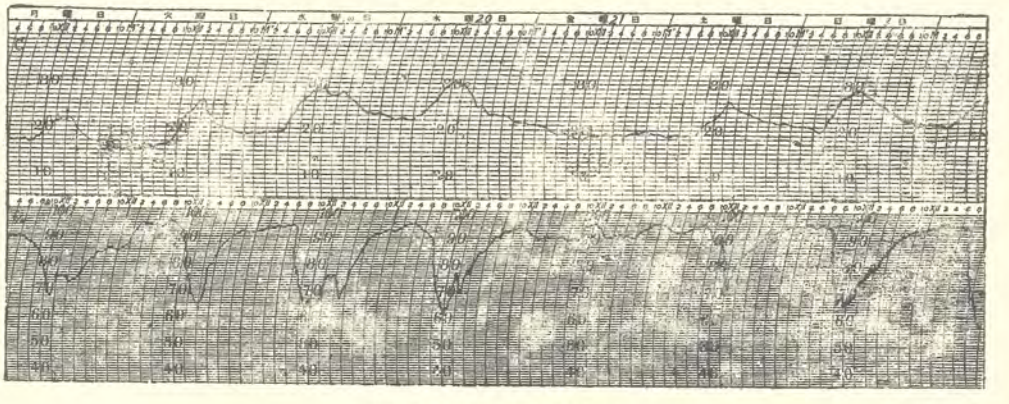
Under the fine weather condition, the water temperature is 1 - 3°C lower than the atmospheric temperature in the forenoon, but this relation becomes adverse at noon and the difference between the two becomes greater with the lapse of time, attaining the maximum (2 - 4°C) at the ti mefrom midnight to daybreak, then comes back to the condition of day-



Tillering stage of the 1st crop



Seeding stage of the 1st crop



Tillering stage of the 2nd crop

Fig.5. Fluctuation of temperature and humidity of the layer of atmosphere in the 1st-- and 2nd crop (1942).

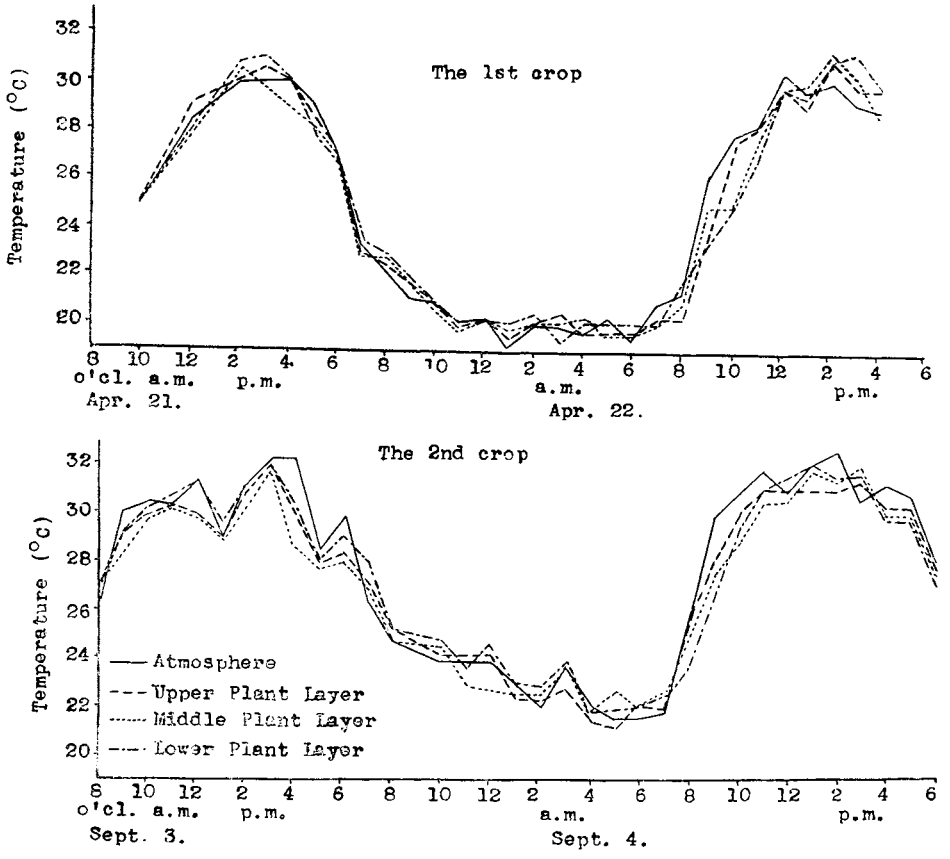


Fig.6. Hourly fluctuation of temperature of the layers of the atmosphere and the rice plants.

time as mentioned above on account of ascending of air temperature following sunrise. The temperature of soil is lower in the forenoon than that of air and water, but at night it becomes more or less higher, especially considerably higher as compared with that of air, and the range of its hourly change in a day is narrower than that of the latters. However, in the 2nd crop, especially in the cloudy weather, it sometimes becomes slightly higher than that of the latters. The soil temperature at each depth is shown in detail in fig.7. In short, the temperature of soil and irrigation water is higher in the 2nd crop than in the 1st crop, about the same with

the air temperature, so far as the comparison made within 20 cm below the ground (the extent of the root system of rice plants) is concerned. As has been mentioned above, the microtemperature of the plant layers is almost the same with the macrotemperature of the atmosphere, it is therefore considered that the former may not exert any special effects upon the growth of the parasite as well as on the resistance of the host plants. Furthermore, the soil temperature within the extent of the root system is

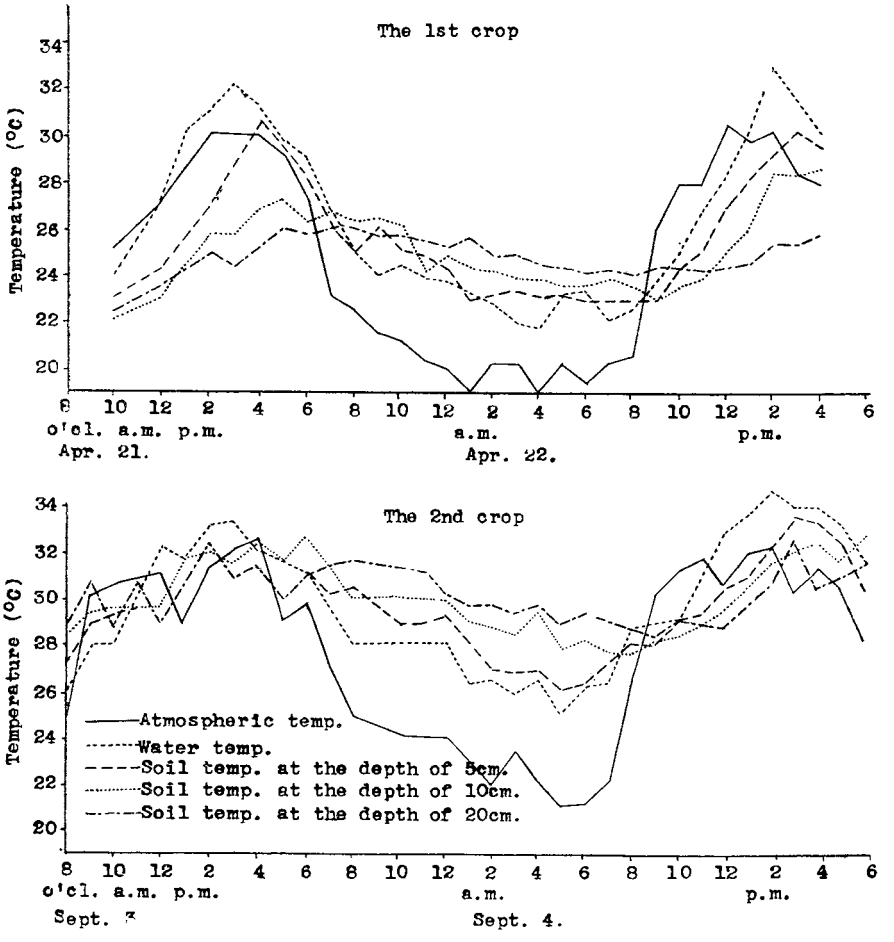

The 1st crop
Temperature (°C)
34
32
30
28
26
24
22
20
8 10 12 2 4 6 8 10 12 2 4 6 8 10 12 2 4 6
o'cl. a.m. p.m. a.m. p.m.
Apr. 21. Apr. 22.
The 2nd crop
Temperature (°C)
Atmospheric temp.
Water temp.
Soil temp. at the depth of 5cm.
Soil temp. at the depth of 10cm.
Soil temp. at the depth of 20cm.
8 10 12 2 4 6 8 10 12 2 4 6 8 10 12 2 4 6
o'cl. a.m. p.m. a.m. p.m.
Sept. 3 Sept. 4.

Fig.7. Hourly fluctuation of the temperature of air, water and soil at the tillering stage of the rice plants in the 1st- and 2nd crop.

also almost the same as the air temperature in its daily average though its range of hourly change is considerably limited in comparison with that of the air temperature. In conclusion, it may be said that microtemperature in the paddy field is almost negligible as a factor of prevalence.

B. Humidity and Amount of Evaporation

The humidity of the plant layers is higher in the 1st crop than in the 2nd crop in consquence of the influencee of the macroclimate, but the difference in both crops is narrower than that of the macro-climate. In the day-time, humidity of the plant layers, especially that of the lower layers, is considerably higher than that of the atmosphere (*vide.* tab.4), but at night the former becomes almost saturated in the same way as the latter.

Table 4. Difference of humidity(%) between atmosphere and plant layers in the afternoon.

Crop	Date	Time (p.m.)	Measurements(%)				Differ. from atmosphere		
			Atmo-sphere.	Upper pl. -l.	Middle pl. -l.	Lower pl. -l.	Upper pl. -l.	Middle pl.-l.	Lower pl. -l.
1	Apr.21	4	75	77	83	91	+ 2	+ 8	+16
2	Sept.3	4	62	81	88	89	+19	+26	+27

Amount of evaporation is less in the plant layers than in the atmosphere, especially at night, because of the fact that the plant layers are prevented from circulation of air and are moistened by transpiration from the leaves. The micro-humidity of the plant layers has an important meaning upon the outbreak of the disease, since such higher humidity is favorable for infection, disease development and sporulation.

C. Dew-drops Remained on the Rice-leaves

(a) Observations under the laboratory conditions

Expt. 1. Water drops were put on the leaves of the potted seedlings with a looped platinum needle and the time required for the evaporation of them was recorded.

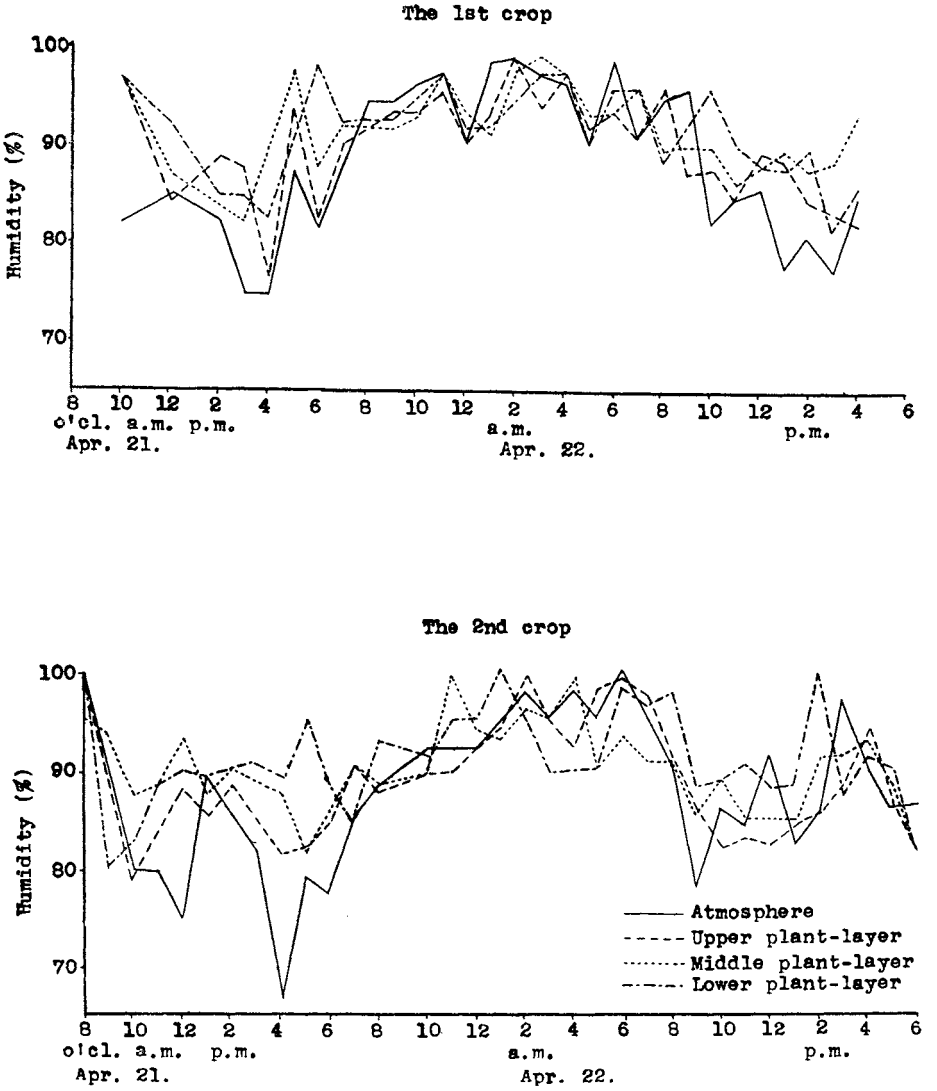


Fig.8. Hourly fluctuation of the humidity of the layers of the atmosphere and the rice plants at the tillering stage of the 1st- and 2nd crop.

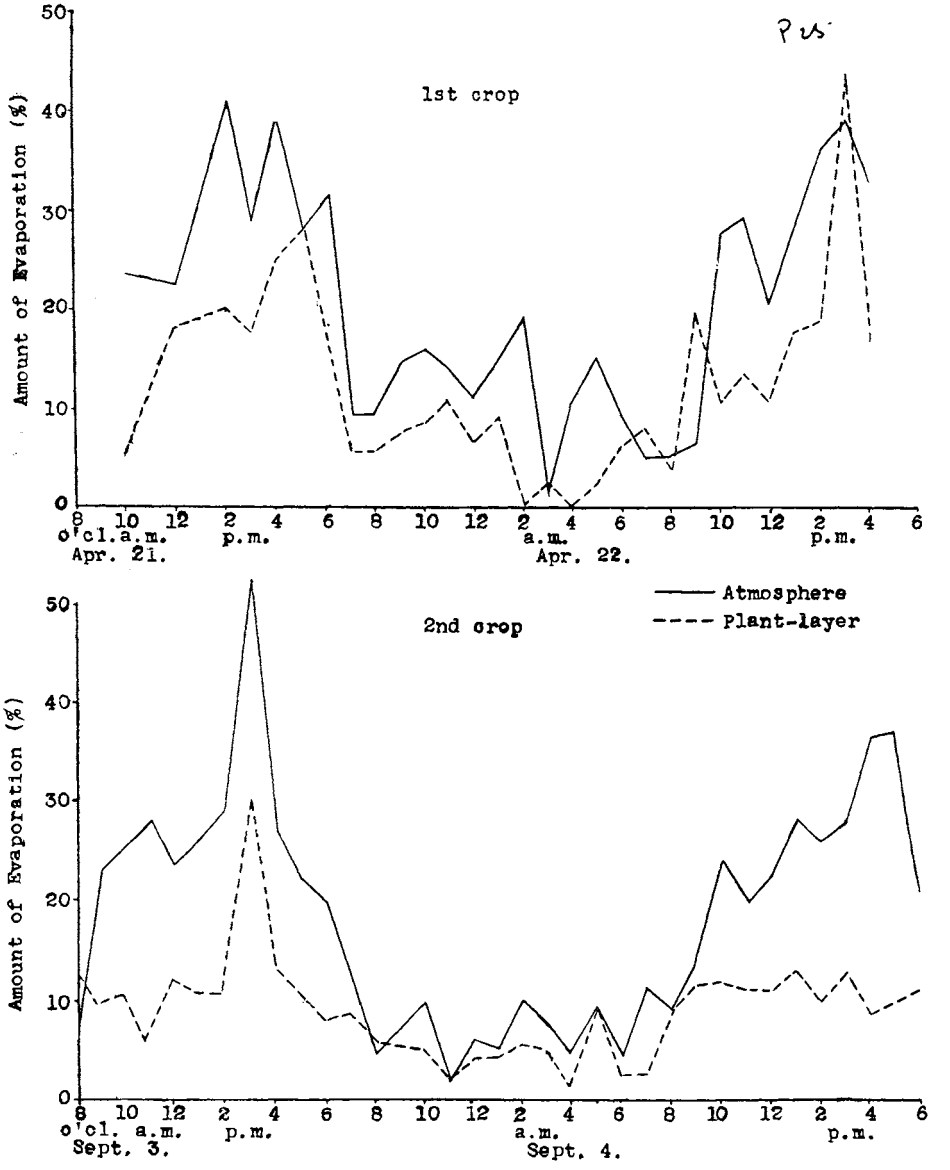


Fig.9. Hourly fluctuation of amount of evaporation of the leaves of the atmosphere and the rice plant at the tillering stage of the 1st- and 2nd-crop.

Table 5. Time required for evaporation of water-drops on the leaves of rice seedlings (Expt, 1),

No.of Drops	Approxim.diam. of drops (mm.)	Time of dropping	Time of evaporation completed	Time required f. evapor.(h.)
1	1.0	a.m. 9.25	a.m. 10.37	1.12
2	1.0	9.27	10.37	1.10
3	1.5	9.28	10.53	1.25
4	1.5	9.29	11.24	1.55
5	1.5	9.30	11.25	1.55
6	2.0	9.23	p.m. 0.33	3.10
7	2.5	9.20	1.4o	4.20
8	2.5	9.18	2.33	5.15

Observed on May 5, 1942 (Fine, But slightly clouded in the afternoon). Temperature and humidity during observation were 26.7 - 28.3°C and 80 - 84%, respectively

Expt.2. water drops put on the leaves by means of an atomizer

In this case, the drops were distributed densely in a fine particle, though some of them dripped by running together.

Table 6. Time required for evaporation of water-drops on the leaves of rice seedlings (Expt. 2).

No of drops	Approxim.diam. of drops (mm.)	Time of dropping	Time of evaporation completed	Time required f.evapor.'h.)
1	1.0	a.m. 11.37	p.m. 1.20	1.43
2	1.0	11.37	1.25	1.48
3	1.0	11.37	1.38	2.01
4	1.5	11.37	1.50	2.13
5	1.5	11.37	1.58	2.21
8	1.5	11.40	2.23	2.43
11	2.5	11.39	3.54	4.15

Observed on May 19, 1942 (Cloudy). Temperature and humidity during observation were 27.0-27.8°C and 85%, respectively

So far as the present experiments are concerned, the time required for the evaporation of the water-drops on the leaves was 1-5 hours, and the larger drops required longer time for evaporation than the smaller, though the drops larger than ca. 2.5 - 3.0 mm. in diam. usually dripped as soon as they were put on the leaves.

(b) Observations under the field conditions

Observ. 1. In order to confirm the time of the first fall of dew as well as the number and size of them in the paddy field, observation was

started at 6 p.m., Apr.25, on the plants at the tillering stage (34.5 cm. high with 4-tillers).

Table 7. Time of the first fall of dew-drops as well as the number and size of them.

No. of tillers	Size of leaves employed (cm)	Number of drops at 2 a.m.				Time of the first fall
		Ca. 1mm. in diam.	Ca. 2mm. in diam.	Ca. 3mm. in diam	Total	
	Length width					
1	2.4 x 0.8	5	5	0	10	p.m. 6.13
2	3.0 x 0.9	9	1	1	11	6.15
3	3.0 x 0.9	12	1	0	13	6.13
4	2.7 x 1.0	5	2	0	7	6.12

Atmospheric conditions of the upper plant-layer during the observation

Observation	p.m.6	7	a.m.2	5	6	7	8
Air temp. (°C)	22.2	20.8	20.3	20.0	20.3	20,8	26.0
Humidity (%)	89	94	100	100	94	94	75
Note	Sunset					Sunrise	wind

Observ. 2. The next observation was made on Apr. 26—27. viz. the early stage of booting (42.0 cm. high, with 17 tillers) for the purpose of getting some information on the time of dewing.

Table 8. Time of dewing.

Kind of leaves	number of drops counted at									Total
	p.m.6	7	8	9	10	11	12a.m.	1	2	
Boot leaf (Tomeba)	1			2	2	1	1			7
Very young leaf	1	1			1	3				6
Young leaf		1		5	2					8
Lower adult leaf					4	2			2	8
Total	2	2	0	7	9	6	1	0	2	29

Atmospheric condition of the upper plant-layer during the above-named observation.

Observation	p.m.5	6	7	8	9	10	11	12	a.m. 2
Air temp. (°C)	27.2	26.0	25.8	25.8	23.8	23.3	22.9	22.2	21.6
Humidity (%)	90	90	84	84	94	94	94	94	100

Considering the various results mentioned above, the dew falls on the leaves, mostly at the apical part of them, in the dusk immediately following sunset at which air humidity increases suddenly as a result of a drop in temperature. Under still and saturated conditions, the dew-drops become somewhat larger with lapse of time, but they drip off when they reach the size of ca. 3.0 mm. in diam. The particles, especially those of

2.5-3.0 mm. in diam. , easily drip off by a light wind, but usually new drops are formed again almost at the same place after a while. Accordingly, the length of time during which a single drop remains on the leaves is hardly measured with exactitude, but under the still conditions, especially in the lower plant layer, the drops stay on the leaves for a considerable length of time which is sufficient enough for the invasion of the host by the fungus. The dew falls earlier and more heavily on the younger leaves than on the older; accordingly, the former may be more frequently invaded by the fungus than the latter. Most of the particles drip off by wind or evaporate in the morning owing to the sudden drop of air humidity and increase of temperature, though thoes on the lower parts of the plant often remain until 9 a.m. or almost noon, if the weather is favourable for them. It is often observed in the early morning when the temperature falls with a run that the surface of the leaves is densely covered with minute dew drops. In such cases, infection may occur heavily, provided the inocula are readily available for inoculation. In conclusion, it may be said that if the weather is calm the dew remains on the leaves from the dusk to the next mo rning during which time the blast fungus can germinate and invade into the host. It should be kept in mind, however, that the setting and evaporation of dew drops are greatly influenced by the macroclimate and not much by the microclimate, though those on the lower part of the plants are somewhat hardly effected by the former.

D. Relation of Temperature and Humidity of the Plant-Layers to the Cultural Method of the Rice-Crop

(a) Temperature and humidity of the layers of seedlings different in the amount of seeds sown as well as in amount of fertilizer.

Temperature and humidity in the plant-layers of 25- day seedings (sown on may 21, 1943) as well as those of the atmosphere are shown in fig. 10. Growth of the seedlings, amounts of some chemical substances in the leaves, and the grade of infection are shown in the following table.

Table 9. Growth, contents nitrogen and carbohydrate, and the grade of infection of the seedlings different in density of growth as well as in amount of fertilizer.

Manuring	Amoumt of grains sown (l.)※	Height of seedlings (cm)	No.of leaves	No.of tillers	Colour of leaves	Total N	C N ratio	Grade of infection
Non-manur.	0.18	30.1	5.3	1.0	Light	2.26	14.31	—
	0.50	21.2	4.3	1.0	Light	1.72	17.77	—
Manur.	0.18	36.1	11.0	1.8	Dark	3.70	4 61	+
※※	0.52	33.5	6.7	1.4	Dark	2.71	8.72	+++

※ Per 1 tsubo (ca. 3.3m²). ※※ 75 kg. of each N, P_2O_5 & K_2O per ha.

As shown in fig. 10, temperature in the plant-layer is always lower than that of the atmosphere, especially during the time of ascending of temperature immediately after sunrise as well as at the time of the highest temperature in the afternoon in which the difference between them is the greatest. The temperature of the plant-layer goes down proportionately to the increase of the amount of fertilizers and the number of the grains sown. Humidity is always higher in the plant-layer to a considerable extent

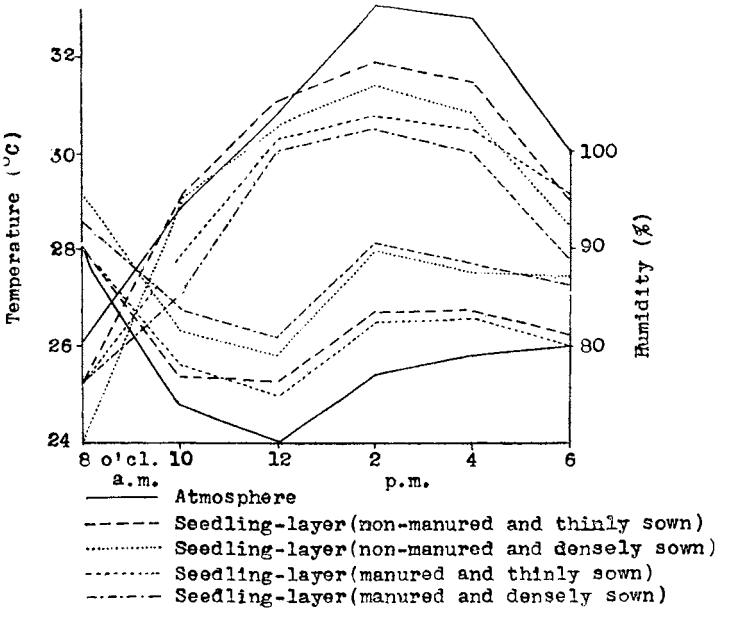


Fig. 10 Temperature and humidity of the layers of seedings different in the density of plant growth as well as in amount of fertilizers.

than in the atmosphere. The difference of humidity between these two layers at noon is as follows:

Table 10 The difference of humidity between atmosphere and plant-layer at noon.

Results of measurement (%)			between atm. and Plant-Layer					
Atmos-	Non-man. 0. 18 l.※	Non-man. 0. 52 l.	Man. 0. 18 l	Man. 0. 52 l.	Non-man. 0. 18 l.	Non-man. 0. 52 l.	Man. 0. 18 l.	Man.. 0. 52 l
6 9	7 6	7 9	7 5	8 2	+ 7	+ 10	+ 6	+ 13

※ 0.18 liter of grains per 1 tsubo.

The disease has not appeared in the experimental plots densely sown and non-manured notwithstanding that the humidity of the above plots is higher than that of the thinly-sown plots. This fact may be due to the resistance of the leaves in the former plots, since their nitrogen content is lower than that of the leaves of the manured plants. Likewise, the fact that the disease has appeared in the plot thinly sown and manured notwithstanding the lower humidity may be attributable to the higher content of nitrogen. In the next place,when comparison is made between the two manured plots which are sown with grains of 0.18 liter and 0.52 liter, respectively, the percentage of infection is higher in the latter than in the former, though the nitrogen content is in the reverse relation. This might be probably due to the higher humidity in the latter. From these facts mentioned above, it is concluded that the temperature of the plant-layer is always lower than that of the atmosphese, while the humidity relation is reversed. These conditions are considered to be important as the environmental factors of the prevalence in seed-beds.

(b) Temperature and humidity in the layers of the rice plants growing at different density after transplanting.

The experiments was conducted with the use of the variety 'Taichu No.65' which was grown under the conditions varied in distance between each other and the number of plants per hill. The observation was made at the culmination of tillering.

Table 11. Temperature and humidity of the layers of plants growing at different density* in conparison with those of the atmosphere.

Distance betw. each hill	No. of seedl. per hill	No. of ranks & files of hills planted	Comparison of temperature and humidity of the atmosphere with those of the differ. phases of pl.-layer							
			Atmosphere		Differ. between atmosph. and pl. -layers					
					Upper		Middle		Lower	
			Temp. (°C)	Hum. (%)	Temp. (°C)	Hum. (%)	Temp. (°C)	Hum. (%)	Temp. (°C)	Hum. (%)
5	1	24x20	26.8	86	−0.7	+4	−0.7	+4	−0.8	+5
10	1	12x17	27.0	83	−0.1	+3	−0.7	+7	−1.4	+4
10	5	12x17	26.8	87	−0.2	+2	−0.4	+4	−0.4	+4
15	1	8x22	25.8	89	+0.1	±0	−0.1	+2	−0.2	+1
15	5	8x22	25.3	89	−0.1	±0	−0.3	+3	−0.8	+1
20	1	6x31	26.0	85	+0.1	−2	±0	+2	±0	−1
20	5	6x31	25.5	89	−0.3	±0	−0.4	+3	±0	−1
25	1	6x31	25.6	84	+0.2	+1	±0	±0	+0.3	±0
25	5	6x31	27.1	83	−0.2	+4	−0.5	+5	−0.2	−3
30	5	5x40	26.0	86	−0.1	+1	−0.2	−2	−0.4	±0

Transplanted on Feb.20, 1943; measured at 11 a.m., Apr.16. 1943.

From the above table, it may be said that coolness and damp of the plant layers are usually in proportion to the density of plants growing, but this relation does not always come about, since the grade of luxuriance which causes the difference of the temperature and humidity differs according to the density of planting and plant-age. The extent of infection appears to be in parallel with the density of planting in the early stage of tillering, so far as the present experiment is concerned. For example, in the plot planted with 1 plant per hill at intervals of 5 cm. infection occurs most seriously, followed by the plots planted 10 cm. apart with 1 and 5 plants in the order named. This relation, however, becomes reversed after the time of tillering. This phenomenon may be attributable to the fact that in the early stage of tillering the seedlings in both plots are equally higher in nitrogen content and susceptible to the disease, but in the densely planted plots dew drops retain for a longer time, consequently, infection occurs more seriously in this plot than in the other, while in the later stage (after tillering) the plants in the densely planted plots become resistant,

*The standard density of transplanting in this island is as follows: The hills (clumps) are transplanted at the distance of 20 x25 (cm.) (200,000 hills per ha.), 4-5 seedlings being used per hill.

because the nitrogen content in the leaves and soil decreases in proportion to the age, and the humidity is lowered more extensively than in the sparsely planted plots where the plants grow more luxuriantly on account of the surplus nitrogen remaining in the soil.

(c) Temperature and humidity of the layers of plants differently irrigated.

It has already been studied by Matsuno *et al.* (1937) in Japan that the micro-climate of the paddy field is greatly influenced by irrigation with cool water from a fountain. The author intended to confirm whether or not the micro-climates of the paddy field and the prevalence of the blast disease are influenced by the method of irrigation under the subtropical conditions. Observation was made in the two paddy fields of 10 a. which are located in close proximity to each other and irrigated with running and

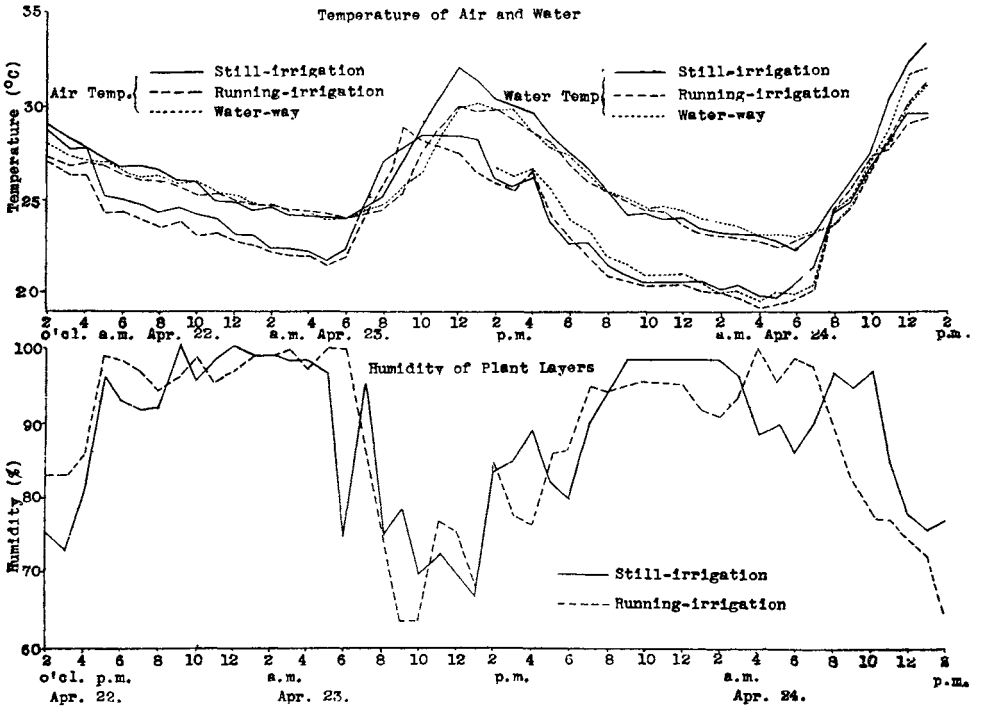


Fig.11. Hourly fluctuation of temperature of water as well as the plant layers and that of humidity of the latter in the paddy field differently irrigated.

still water, respectively. As seen in fig. 11, in the day-time temperature of still water is somewhat higher (ca. 2°C) than that of running-irrigation and water-way, the latter two being almost the same in coolness, though slightly cooler in the last-named. But at night, all of them become almost indistinguishable, though the temperature of still water slightly falls after midnight up to sunrise. The temperature of air above the water-way is usually higher than that of the plant-layers. Moreover, in the case of the latter the plot of the still water is warmer than that of the moving one, though the difference between them is only 0.5 - 1.0°C. At night, especially at daybreak, humidity of the plant layers is rather lower in the plot of the running water than in that of the still water, but in the day-time no definite tendency is seen between them. As has been mentioned above, the difference of temperature and humidity between these two plots is rather slight, since the running water is warmed during the course of running through the water-way and becomes as warm as the atmosphere. It seems probable that such a slight difference as mentioned above is not sufficient enough for exerting influence upon the prevalence, so far as the atmospheric temperature within the range of the optimum conditions for the fungus growth as shown in the present observation is concened.

E. Insolation

(a) Hourly change of insolation (solar radiation) in the 1st and 2nd crops.

As regards the insolation observed during the vegetative growth of rice plants of the 1st and 2nd crops in Taichung (24°09'N) is shown in table 12 and fig.12.

Table 12. The amount of insolation during the different periods of growth of rice plants in the 1st and 2nd crops at Taichang(24°09'N).

Crop	Growth stage	Periods observed	Insolation on horizontal surface (g. cal. / cm^2 per day
1	Seedling	Feb.10 - Feb.14	438.2
	Tillering	Apr. 1 - Apr. 5	268.7
2	Seedling	July 10 - July 14	648.0
	Tillering	Aug.19 - Aug.23	581.0

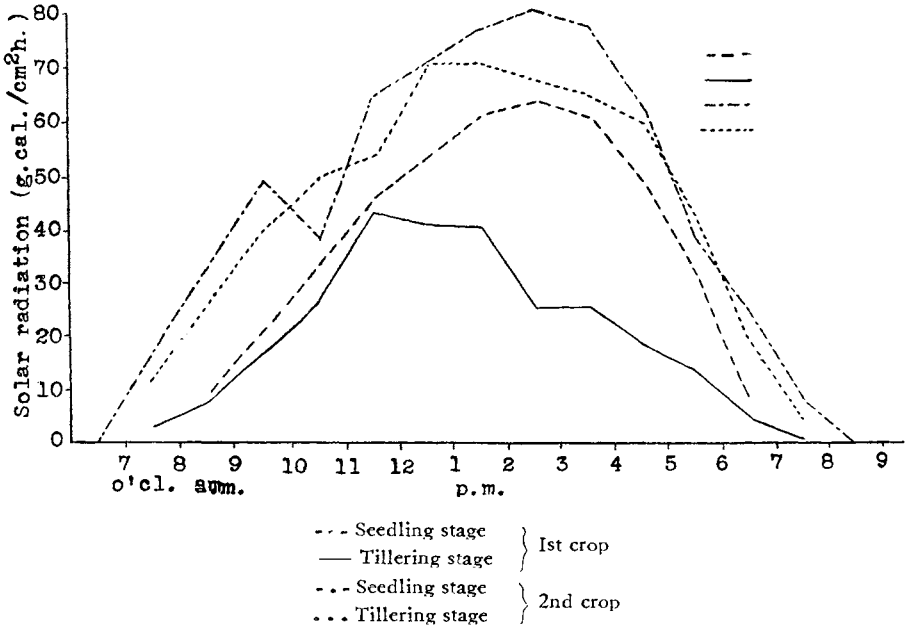


Fig.12. Hourly change of insolation during the diffeernt growth stages of the lst and 2nd crops.

As shown in the above table and figure, the solar radiation is weaker in the lst crop than in the 2nd, since in the former, especially in the tillering stage, the length of day is shorter and the radiation in each hour is less on account of cloudiness.

(b) Intensity of light at the horizontal surface of the plant layers

Comparison of the solar radiation in the open field with that in the plant layers of the paddy field could not be directly made, since a proper instrument was not kept in hand, but it may be presumed from the data of the observation on the intensity of illumination at the horizontal surface, since the study of Matsuno *et al.* (1937) shows that the amount of the solar radiation and that of the intensity of illumination is in parallel relation, so far as the observation in the paddy field is concerned. The intensity of illumination is weakened severely in the plant layers due to the shade of leaves as will be seen in the following instance.

Table 13. Intensity of illumination at the horizontal surface in the layers of atmosphere and plants.

Crop	Date	Time (p.m.)	Weather	Intensity of illumination (lux)			
				Atmosph.	Plant-layers		
					Upper	Middle	Lower
1	Apr.21	4	Fine	1,400	900	350	200
		5	Fine	1 600	1,000	800	400
2	Sept.2	4	Cloud	3,200	1,750	2,210	1,250
		5	Cloud	3,500	2,100	1,100	1,000
		6	Fine	2,000	1,100	800	400

As seen in the above table, intensity of light is in almost parallel to the grade of luxuriance of leaves, and this phenomenon is also confirmed by the observations made in the paddy plots prepared by different cultural methods, such as, density of planting, time of transplanting, time of manuring, amounts of fertilizers, etc., though the data of them will not be given here.

In conclusion, it is inferred that the intensity of sunlight in the plant layers of the paddy field is less in the lst crop than in the 2nd, since in the former not only the solar radiation is feeble, but also the leaves grow thicker than in the 2nd crop.

F. Wind

Although there are some observations and experiments which indicate that wind predisposes the plants to be easily invaded by the blast fungus as a result of mechanical injury (Kikkawu,1899; Sakamoto, 1939,1940), wind is thought to be rather useful for preventing infection by the reason that it hasten to dry the dew drops on the leaves. As seen in table 14, the air in the plant layers is hardly disturbed by wind and, in consequence, is suitable for the outbreak of the disease.

Table 14. The wind velocity in the layers of plants at the culmination of tillering in comparison with that in the atmosphere.

Crop	Date	Time (p.m.)	Wind Velocity (m / sec.)			
			Atmosph.	Plant / layers		
				Upper	Middle	Lower
1	Apr.22	2	0.43	0.07	0	0
2	Sept.1	5	1.87	1.10	0.12	0
	Sept.1	6	0.61	0.19	0	0
	Sept.1	8	0.05	0	0	0
	Sept 3	2	2.80	1,33	0.19	0
	Sept.3	4	1,87	0.83	0.11	0

From the results of the observations on the micro-climate of the paddy field hitherto mentioned, the following conclusions are induced. The micro-environments of the plant layers are suitable for the outbreak of the disease by the reason that it is cooler, wetter, less light and windy than the atmosphere provided that the temperature lies within the limit of the range favourable for the fungus. Furthermore, such micro-environments differ with the grade of luxuriance of rice plants, the latter being influenced by the cultural methods, such as amount of grains sown, density of planting, irrigation, ages of plants, time of manuring, and amount of fertilizers given, etc., as has already been stated. The above-mentioned features of the micro-climates of the plant layers are more distinct in the lst crop than in the 2nd crop, since they are influenced not only by the macro-climates but also by the growth conditions of the plants.

As will be mentioned in chapters III and IV, among these micro-environmental conditions, micro-temperature condition has the most intimate relation to the prevalence of the disease, but the remaining factors are not considered much significant, although these are considerably different from the macro-environments, whereas the micro-temperature of the plant layers is almost indistinguishable from the macro-temperature of the atmospher. In view of the data mentioned above, it may be concluded that the prevalence is largely influenced by the macro-climates, but not much by the micro-climates.

CHAPTER III

RELATIONS OF THE TROPICAL ENVIRONMENTS TO GROWTH OF THE RICE BLAST FUNGUS

Section 1. Relation of Temperature to Growth of The Rice Blast Fungus

The relation of temperature to the growth of the rice blast fungus on the artificial media as well as on the living host has been extensively studied by many workers (Suematsu, 1916; Nishikado, 1917, 1926; Sawada, 1927; Sueda, 1928; Kuribayashi, 1928; Abe, 1930, *a*; Hemmi & Abe, 1931,1932; Hemmi *et al.*, 1936;Konishi ,1933; Yoshii 1936; Suzuyi, 1941, 1944; Hashioka, 1943,*d;* Henry & Andeosen, 1948; etc.). From these studies it is summarized that all the processes of growth, such as growth of mycelia, germination of conidia, formation of appressoria, invasion of the fungus into the host, development of the disease, formation of conidia, etc. are equally vigorous at 24 - 30°C, especially at 26 - 28°C, and the minimum and maximum are 7 - 8°C and 34 - 36°C, respectively.

In order to confirm the relation of temperature to invasion of the fungus into the host as well as to the development of the disease under the subtropical conditions, the author made further studies in almost the same way as used by Hemmi & Abe (*loc.cit.*), since the studies of all the workers mentioned above have been conducted at the temperatures of a rather limited extent, and that alone is not sufficient to interpret the tropical phenomenon in full.

Table 15. Results of the experiment on the relation of temperature to invasion of the blast fungus into the host plant.

Expt. temp. (°C)	Water drops retained for (h.)	Incubat period (days)	No. of lesions per plant	Remarks
15.0±1.0	5	-	0	Approximately similar to the temp. of the average of day and night in the seedling stage of the lst crop at Taichung
	8	-	0	
	11	-	0	
	14	-	0	
19.0±0.5	5	6	0.01	Approximately similar to that of the night in the tillering stage of the lst crop
	8	6	0.01	
	11	6	0.42	
	14	6	1.00	
26.0±0.5	5	6	0.01	Approximately similar to that of the day-time in the tillering of the lst crop and the night in the seedling as well as tillering of the 2nd crop
	8	6	0.90	
	11	6	2.50	
	14	4	4.10	
28.0±0.5	5	6	0.09	Approximately similar to that of the average of day and night in the seedling and tillering of the 2nd crop
	8	5	0.09	
	11	6	3.80	
	14	5	7.00	
32.0±0.5	5	6	0	Approximately similar to that of the day-time in the seedling and tillering of the 2nd crop
	8	6	0.09	
	11	6	0.08	
	14	6	2.80	

From the above table, it is clear that the blast fungus invades into the leaves most easily and rapidly (mostly within 5 - 11 hours) under the conditions of the day-time in the tillering stage of the lst crop as well as under those of the night-time in the seedling and tillering stage of the 2nd crop, while under those of the night and day-time in the former and latter period, respectively, more prolonged time, usually 14 hours or more, is necessary for the invasion, so far as only the temperature factor is concerned. It is also clarified that under the conditions of the seedling stage of the lst crop invasion does not occur on account of coolness no matter how long water drops stay on the laaves.

Experiments on the relation of temperature to the development of the disease were conducted by keeping the inoculated plants (incubated for 24 hours at 28°C) in the glass boxes placed in the glass house where air temperature and humidity are regulated to become almost the same

as noticed in the paddy field of either the lst-or 2nd crop. In this connection it must be taken into consideration whether or not the development of the disease is influenced by the predisposition of the host. Accordingly, a preliminary experiment was undertaken by keeping the plants for a few days at different temperatures previous to the inoculation.

Table 16. Results of inoculation upon the rice seedlings previously kept at different temperatures for a few days.

Days	15 - 20°C	20 - 24°C	26 - 29°C	30 -33°C
2	3.45※	3.50	3.20	3.20
5	4.58	3.08	3.00	2.57

※Number of lesions per seedling.

It is clear from the above table as well as from the experiments shown in the next chapter, that resistance of the plants is reduced by coolness, although this effect is hardly recognizable in the case of the 2-day treatment. These results, however, are in opposition to those

Table 17. Results of the lst experiments on the effect of temperature upon the development of the disease.

Temp. (°C)	Humidity (%)※	Incubat. period (Days)	No of lesions per plant	Remarks
10 - 18	60 - 82	-	0	Approximat. similar to the temp. of the aver. of day & night in seedl. stage of the lst crop.
16 - 20	93 - 99	5	0.30	Approximat. similar to that of the night in tillering of the lst crop
20 - 26	80 - 85	4	1.00	Approximat. similar to that of the day-time in tiller. of the lst crop.
25 - 29	85 - 93	4	1.58	Approximat. similar to that of the night in seedl. & tiller. of the 2nd crop.
28 - 34	60 - 85	4	2.05	Approximat. similar to that of the day-time in seedl. & tiller. of the 2nd crop.

※Presuming from the studies of Tochinai & Komiya(1939), the effect of humidity during the incubation period on the rice-blast resistance is thought to be almost negligible, so far as the present experiments extending such a few days are concerned.

Table 18. Results of the 2nd experiment on the effect of temperature upon the development of the disease.

Day-time		Night-time		Incub. period (Days)	No. of lesions per plant	Length of lesions(cm)	Remarks
Temp. (°C)	Humid. (%)	Temp. (°C)	Humid. (%)				
13-19	85-95	13-19	85-95	-	0	-	Approxim. similar to the temp. of the seedl. st. of lst crop
25-27	75-85	13-19	85-95	5	0.57	0.13	Approximat. similar to that of the tiller. of the lst crop
25-27	75-85	25-27	75-85	4	3.20	0.24	
24-27	96-100	24-27	96-100	4	3.78	0.39	Approximat. similar to the seedl. & tiller. of 2nd crop
29-32	53-72	24-27	96-100	4	3.10	0.30	
29-32	53-72	29-32	53-72	4	1.28	0.28	

given in tables 17 - 19 in which it is shown that the disease spreads more rapidly with increase of temperature in exactly the same manner as noticed in the case of the invasion of the fungus. It is considered that the results shown in tables 17 - 19 may be due to the effect of temperature on the growth of the fungus and by no means due to that on the host plants, since the infection has taken place mostly in less than 5 days, during which period the effect of temperature on the plants is practically negligible, as has already been mentioned.

Table 19. Results of the 3rd experiment on the effect of temperature upon the development of the disease.

Day - time		Night -t ime		Incub. period (Days)	No. of lesions per plant	Length of lesions (cm)	Remarks
Temp. (°C)	Humid. (%)	Temp. (°C)	Humid. (%)				
18-24	92-100	18-24	92-100	5	1.00	0.18	
24-27	72-87	18-24	92-100	4	3.21	0.28	Appoximat. similar to the temp. of the tiller. of the lst crop
24-27	72-87	24-27	72-87	4	4.90	0.40	
27-30	90-100	27-30	90-100	4	6.41	0.45	
31-34	52-73	27-30	90-100	4	4.02	0.40	Approximat. similar to the temp. of seedl. & tiller. of 2nd crop
31-34	52-73	31-34	52-73	4	2.06	0.52	

The above relation of temperature to growth of the blast fungus is important as a controlling factor of prevalence, as will be evidenced by the following example taken from the actual circumstances noticed in Taichung district (24°09'N). In the first crop of the above district, infection and spore formation are almost unrecognizable during the seedling period (February), at which time temperature is about 15°C on an average and often descends to 10°C and downwards, likewise they are not much enhanced even in the early stage of tillering (March) ,although the weather is getting slightly warmer in this period. On the other hand, in the tillering stage (April) as well as in the heading stage (May) ,during which time temperature is 19 - 21°C and 23 - 25°C, respectively, infection occurs followed by spore formation. In the 2nd crop, the seedling and tillering (August) periods are the critical time, the temperature being 25 - 28°C, and the heading-maturity period (September, 23-25°C) is moderate in initial infection. In other words, the temperature condition of the 2nd crop is more favorable for infection and spore formation than that of the lst crop, although the disease is virtually not so prevalent by the reason which will be mentioned later. As for the development of the disease after infection, all the growing periods of the lst-and 2nd crop except for the seedling stage of the former are favorable, so far as the temperature condition is concerned. Although the mean temperature during the seedling and the tillering periods of the 2nd crop is aboot 28°C which is the most favorable for growth of the fungus, the temperature of the daytime is usually higher than this optimum point. In the subtropical countries, it is not unusual that the temperature ascends to more than 32°C which is the maximum for the growth of the blast fungus. For example, at Chieng-teng district, in Hainan island, about 15 per cent of the total hours extending over the months of June to August are of the temperatures above 32°C, as has been shown by the author (1943,b). on the other hand, in Taichung the temperautre during the months of April to June and September to November, especially May and October, is 24 - 25°C throughout the day and night, and

is very favorable for the growth of the parasite. From the studies on the temperature relation of the conidial germination of the present fungus, Sueda (1928) suggested that in Taipeh (25°02'N) the disease may be able to spread almost throughout the year, although it is most prevalent in the early summer (from the end of May to the middle or the end of June) and autumn (from the beginning of September to the early part of October). This presumption is in accord with the results of the field experiments conducted by Tokunaga & Cheng (1943) and also with the author's which indicates that the disease outbreaks severely twice a year as has been mentioned above, but it hardly occurs in midsummer (July-Aug.) and never occurs in winter (Dec. - Mar.) even on the seedlings which are susceptible to the disease. However, the fact that the actual season of the prevalence in the subtropical regions is restricted to the tillering stage (April) and to the maturity stage (from the latter half of May to June) of the lst crop. is due to the reason that the prevalence in nature is controlled not only by the relation of temperature to the growth of the parasite but also by some other factors, such as the relations of temperature to the resistance of the host (*cf*.chapt.IV), the relatons of age of the host to resistance (*cf*.chapt.V), etc.

In conclusian, it may be said that the relation of temperature to the growth of the fungus is the most important factor for the prevalence in nature regardless of the districts exclusive of the tropical countries, where the temperature is always suitable for the fungus growth throughout the year. Especially in the temperate region of the higher latitudes where the temperature is favourable for the growth of the parasite only in the midsummer, the natural prevalence is controlled only by the temperature condition effecting upon the part of the parasite.

Section 2. Relation of Humidity to the Growth of the Rice Blast Fungus

As to the relation of humidity to the growth of the funugs in question, it has already been clarified by some investigators in the

following points, viz., the mycelial growth on the culture media is most vigorous at about 93 per cent of relative humidity and is gradually declined with increase or dicrease of it (Abe,1941); the conidia are able to germinate in the humidity more than 96 per cent and most vigorously in water drops (Hemmi & Abe,1932); the fungus is able to invade into the hosts when water drops are present and the humidity is more than 92 per cent (Hemmi & Abe,1932) ; conidia are formed only in the humidity above 89 per cent, especially most abundantly at saturation point (Hemmi & Imura, 1939), etc. The author intended to study the relation of humidity to the development of the disease and also to the dissemination of conidia, since these points have not yet been thoroughly studied up to this time. For the former, 5 plants were cultured in a bottle (500 cc. in capacity) with Fukaki's solution (1929) and inoculated when they attained the height of 30 cm. All the bottles were plugged with paraffined mosline so as to prevent the evaporation of the culture solution. After 24-hour incubation at 28°C and 100 per cent humidity, 3 bottles were removed to a large glass jar (30 litre in capacity) in which humidity was controlled by means of sulphuric acid.

Table 20. Results of the lst experiment on the relation of humidity to the development of the disease.

Humidity (%)	Presence of water drops on leaves	Incub. period (Days)	No. of lesions per leaf	Length of lesions (cm)※	Aerial mycelia※	Formation of conidia※※	Nature of lesions※※
97-100	+	4	0.9	0.30	+	±	(i)
90- 92	+	4	1.2	0.30	—	±	(i)
86- 88	—	4	1.4	0.30	—	—	(i)
77- 80	—	4	0.9	0.25	—	—	(ii)
75- 78	—	4	1.8	0.25	—	—	(ii)
44- 47	—	5	1.5	0.21	—	—	(iii)

※ Measured 7 days after infection (Temperature during the experiment was 15-27°C).

※※ (i) Typical; the necrotic zone is wide; development is fast.

(ii) Light; venenate zone is wide; development is slightly slow.

(iii) light; dried; venenate zone is wide; devlopment is slow

Table 21. Results of the 2nd experiment on the relation of humidity to development of the disease.

Humidity (%)	Presence of water drops on leaves	Incub. period (Days)	No. of lesions per leaf※	Length of lesions (cm)※	Aerial mycelia※	Formation of conidia※	Nature of lesions
98 - 100	+	5	1.0	0.25	+	+	(i)
91 - 95	+	5	0.7	0.25	—	++	(i)
91 - 94	+	5	0.6	0.25	—	++	(i)※※
82 - 90	+	5	0.5	0.25	—	±	(ii)
80 - 85	—	5	0.9	0.25	—	—	(ii)
77 - 80	—	5	1.0	0,20	—	—	(iii)

※ Measured 7 days after infection (Temperature during the experiment was (28 - 32°C).

※※ Almost same as (i), but development is slightly slow.

So far as the above experiments are concerned, no definite tendency has been observed as regards the relation of humidity to the number of lesions, but the extension of the lesions and the rapidity of development of the necrotic and disintegrated zones (Yoshii. 1937) are clearly correlative to the humidity, though in the saturated humidity the development of the disease is somewhat repressed later. Such phenomena seem to be due to the physiological effect on the host plants as a result of a prolonged exposure to the high humidity. As to the formation of conidia, the results of the present experiment are in accord with those of Hemmi and Imura's (1939).

Concerning the dissemination of conidia, the experiments were conducted by allowing the diseased ears to keep growing in the above mentioned bottles so as to make the conidia drop on the slide glasses placed immediately below (30 cm) the above-named ears. Then the number of conidia fallen during 12 hours on the area of 4.0 x 2.5 (cm) of the above glasses coated with the mixture of glyceline and gelatine was counted.

Table 22. Results of the experiments on the relation of hamidity to dissemination of conidia of the blast fangus.

Expt. no.	Humidity (%) 95 — 99	90 — 93	87 — 89	81 — 84	75 — 80	60 — 65
1	650※	124	0	0	0	0
2	226	101	18	0	0	0

※Number of the conidia collected.

As is seen in the above table, the conidia do not disseminate in the humidity less than 90 per cent. It was clarified by a microscopical observation that the failure of disseminating conidia in the lower humidity is due to the inability of conidial formation. It was pointed out by Kuribayashi *et al.* (1941) that dissemination of conidia in nature occurs only at night, but no definite relation between dissemination and humidity has yet been confirmed, since the number of conidia gathered in their experiment was too small. In the lst crop in 1943, the author obtained the following results by counting the conidia collected in the same manner as mentioned above from the air 30 cm high above the surface of the irrigation water in the paddy field. According to fig.13 dissemination of conidia is in intimate relation to the humidity. It occurs only in the humidity above 90 per cent. Moreover, radiation has an important bearing on the conidia dissemination, since it is almost delayed during the day-time even in the case of the higher humidity. As regards temperature, Kuribayashi (1928) pointed out that dissemination is more active at 25 - 28°C than at 20°C. However, so far as the present experiment is concerned, the effect of temperature upon dissemination seems to be almost negligible. since the former temperatures of the above-named author's experiment correspond to those of the day-time of the present experiment in which the dissemination is great.y restricted, and the latter temperature corresponds to that of the night during which the spores are disseminated to a great extent. In all probability this phenomenon may be related to humidity and radiation rather than temperature.

From the above-named studies, the following conclusion can be drawn. The relation of humidity to the growth of the blast fungus appears to have no important bearing on the prevalence of the disease, so far as the humidity during the period of the rice-crop is concerned, since the humidity of all the rice-crop regions is almost the same (about 80 per cent, of chapt. II) regardless of latitudinal difference. Fig.13. Dissemination of conidia in the paddy field as well as its temperature and humidity

relation during observation.

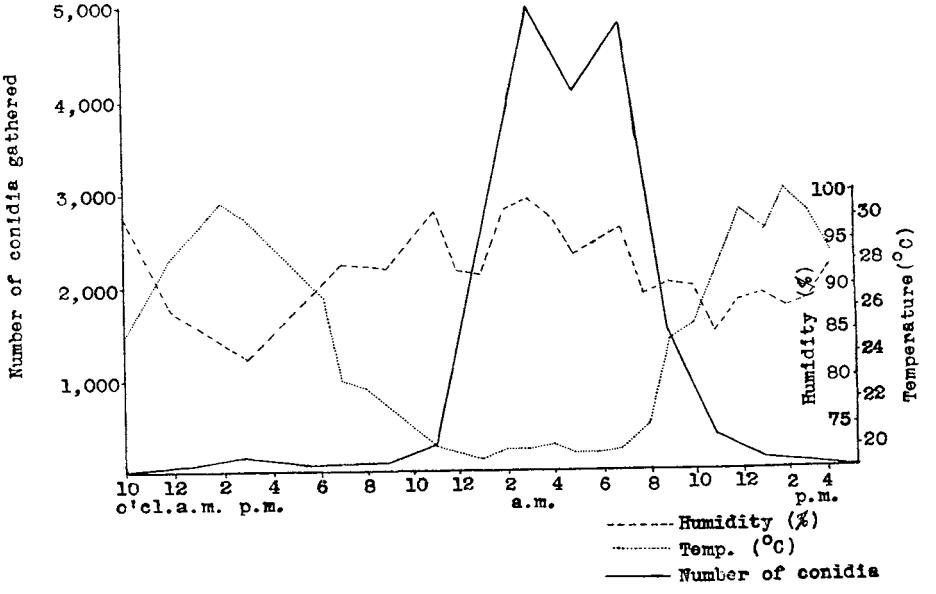


Fig.13. Dissemination of conidie in the paddy field as its temperature and humidity relation buring observation.

The relation between the prevalence and the retention of water drops on the plant bodies also is of no significance by the same reason as mentioned above, although the presence of water drops is quite important for the invasion of the blast fungus into rice plants.

Table 23. Frequency of dew, mist and rain in Taichung (24° 09'N)

Water drops	Growth stage※ 1※※	2	3	4	5	6	7	8	9	10	11	12	Total
				oooooo		ooo							
Dew	9	8	8	12	11	21	16	17	17	18	11	12	160
Mist	2	3	4	3	1	1	0	0	1	2	2	4	23
Rain※※※	6	9	6	12	8	12	11	9	7	1	2	6	89

※----- Seedling or heading as well as maturity stage.

——Vegetative duration in paddy fields.

oooo Prevalent duration.

※※ Month

※※※ Number of days with precipitation≧1.0 mm.

A sshown in the above table, dew is little in winter and spring which cover the most part of the lst-crop season and is abundant in summer and autumn i. e. the season of the 2nd crop. Dew drops stay on the plants for more than 10 hours from dusk or midnight to early morning (*vide*. chapt. II. sect. 2) during which time the fungus is able to invade into hosts if temperature is favourable. Nevertheless, it can not be regarded as a controlling factor of prevalence, since the disease hardly occurs in the 2nd crop notwithstanding the fact that in this season dew is heavier and temperature is more favorable during night than in the lst-crop. Mist is almost negligible as a controlling factor, since its occurrence is very limited. The rain falls more frequently in the period of the vegetative growth of the 2nd crop than in that of the lst one, and this relation becomes contrary to the above after heading. Moreover, the rain lowers the air temperaturs, in the 2nd crop down to the point optimum for growth of the fungus, and in the lst crop to that below the optimum. Notwithstanding this fact the disease does not occur so much in the 2nd crop. Therefore, the rain is not considered to be a controlling factor of prevalence. As for the cause of difference of epidemic of the present disease between the lst crop and the 2nd in Formosa, Sawada (1935.*b*) emphasized the difference of light and humidity conditions which may effect chiefly the parasite. However, as stated above, the relations of the environmental conditions other than the temperature factor to the growth of the fungus are of minor importance as the cause of epidemic in the subtropical regions.

CHAPTER IV.

RELATION OF THE TROPICAL ENVIRONMENTS TO THE RESISTANCE OF THE RICE PLANTS TO THE BLAST DISEASE

Section 1. Relation of Temperature to the Resistance of the Rice plants

The difference of temperature during cultivation of the rice plants between the temperate regions and the tropical ones (*Vide.* chapt. II) effects not only the growth of the blast fungus (*Vide.* chapt. III), but also the resistance of the rice plants, as has already been pointed out by the author (1943, *c*; 1944, *b*). As early as 1898, Hori reported that the rice blast disease occurs more severely in the paddy field which is close to the stream of cold water. Then the outbreak of the blast disease due to the influence of exposure to cold is commonly called "Hie-imochi" (chill rice-blast). Hemmi & Abe (1932) and Abe (1933,*b*) pionted out that the severity of seedling blight (so-called "Nae-imochi"), *i. e.* the symptom of the blast disease produced in the very young seedling state, is enhanced in proportion to the decrease of soil temperature, so far as the temperatures studied by them (20°, 24°, 28°, and 32°C) are concerned. As to the relation of the soil temperature to the disease of the leaves of the seedlings, they came to the conclusion that the injury was slightest at 28°C, the optimum for growth of the seedlings, followed by 24° and 32°C, and severest at 20°C as same as in the seedling blight mentioned above. They (Abe, 1936, 1939; Hemmi *et al.*, 1941) also pointed out that when the plants were exposed to the soil temperatures of 18 - 24°C and 20 - 29°C during the booting and heading stages, the necks of panicles of the plants grown under the former temperature conditions were attacked more severely than those under the latter. They also reported that the

necks of panicles were injured more heavily when the plants were kept at the air temperatures of 12 - 18°C for 7 days during the heading stage than at 26 - 32°C. A somewhat similar experiment was made by Doi (1944) by means of irrigation with cool water for certain days before or after inoculation, or exposing the plants to a cool air, but he was unable to obtain any conclusive data. Tochinai & Komiya (1939) reported that the functional resistance of the rice seedlings to the blast diseese is decreased by the high temperature treatment, that is, heating the surrounding air or immersing the plants in hot water. They confirmed that the percentage of infection increased proportionately to a rise of temperature until the maximum was reached, and beyond the maximum point it decreased in consequence of rising temperature and sometimes it became lower than that on the control plants. In the present experiments studies have been centered upon the following points: (1) Relation of the difference in air temperature between the seasons of the 1st- and 2nd crop to the resistance of the plants concerned (Hashioka, 1943, *c*); (2) Effect of temperature on the plants at different ages in order to clarify whether the resistance is due to the physiological change of the plants or to the so-called disease escaping resulted from the difference in the rate of the growth of the plants under different temperature conditions, although in some cases there is found no sharp distinction between the two; (3) Relation of temperature to the resistance of the rice plants of both crops grown under different nutritional conditions, with special consideration of the fact that under the subtropical conditions the effects of manuring on the growth as well as the resistance of the plants are very different between the lst crop and the 2nd (Hashioka, 1944, *a*).

The methods used in the present investigations are as follows: Glass boxes of 1.3 x 0.8 x 0.8 (m.) were placed in the ordinary glass-house, temperature being maintained by means of nichrom wires connected with mercury-toluol hose regulators. In the present experiments the following four different temperatures were mainly taken into consideration by the reason mentioned below. Lower temperatures (10 - 20°C), corresponding to those of the seed-bed of the lst crop; moderate temperatures (20 - 25°C),

corresponding to those of the tillering period of the lst crop; optimum temperatures (26 - 28°C) corresponding to those of the seed-bed and the tillering period of the 2nd crop; higher temperatures (30 - 32°C), *i. e.* the noon condition of the seed-bed and the tillering period of the 2nd crop. In the experiments of the soil temperature, all the plants were grown in the glass cylinders kept in the water bath which was heated at a desired constant temperature by the same method as already mentioned. In some cases, however, the above pots were immersed in some solutions of electrolyte* of different concentrations provided with zinc electrodes which become calorific when made contact. By use of this method experiments were conducted at a time at seven different soil temperatures ranging from 15°C to 35°C. In the experiments on the nutritional problems mentioned above, seedlings were grown in the glass cylinders containing 700 g. of soil** with the fertilizers of different quality as well as quantity under different conditions of air temperature. Unless otherwise mentioned, all the plants used in the experiments were of the same age regardless of the temperature under which they were grown, but in some cases the plants kept at lower temperatures were sown somewhat earlier than the remainders so as to secure apparently the same growth condition as the others at the time of inoculation. In this connection, it is to be remembered that the plants kept at the higher temperatures tend to grow more upright and rigidly than those under the lower temperatures, in consequence, it is more difficult to retain water drops on the former than on the latter. However, this handicap was almost avoided by dispersing a small quantity of spore suspension in extremely fine particles.

A. Relation of Air Temperature to the Resistance of the Leaves of the Rice Seedlings at Different Ages or of Different Varieties

Inoculation was made simultaneously on the seedlings grown at different temperatures for varied length of time. The results are shown in the following table.

*NaCl was used throughout the course of the experiments.

** The soil contained 0.18% of N, 0.35% of P_2O_5 and 0.23% of K_2O in dry basis

Table 24. Results of the inoculation on the 15-, 30-, and 45-day seedlings grown under different air temperature conditions

Air temt. (°C)	Growth duration (Days)	plant Height (cm)	No. of tillers per seedl.	No. of leaves per seedl.	Total lenght of leaves (cm)	width of leaves (cm)	No. of lesions per seedling	No. of lesions per 1 cm of leaf length	Length of lesions (cm)
14-20	15	16.6	1.0	2.6	12.9	0.3	0.11	0.009	0.28
	30	33.6	1.0	3.6	50.9	0.5	3.39	0.067	0.46
	45	56.0	1.0	5.6	116.6	0.7	7.54	0.065	0.50
27-29	15	23.1	1.0	2.6	21.1	0.3	0.14	0.007	0.25
	30	36.7	1.0	4.7	79.6	0.5	0.71	0.009	0.34
	45	62.7	1.0	7.0	174.2	0.7	3.59	0.021	0.42

Sowing: Nov. 20(45-day seedlings), Dec. 5(35-day seedling), Dec. 20(15-day seedlings) in 1942. Inoculation: Jan. 4, 1943.

As shown in the above table, the seedlings grown at the lower temperatures were usually more susceptible than those at the higher with the exception mentioned below, so far as the comparison made with the plants of the same age was concernced. The fact that the 15-day seedlings grown under the lower temperature condition were hardly affected by the disease, was due to the nature of the leaves of the very young seedlings (*Vide*. chapt. V). Considering the possibility of the disease escaping due to the difference in growth rate of the plants grown under different temperature conditions, the inoculation experiment was also conducted simultaneously with the use of the plants different in growth period which is prolonged in proportion to coolness. The result of this experiment also showed that the susceptibility of the seedlings was in parallel relation to coolness under which they were grown.

Table 25. The results of the inoculation on the seedlings grown at different tempertures for different periods.

Air temp. °C		Humidity (%)	Growth duration (Days)	Height of seedl. (cm)	No. of tillers per seedl	No. of leaves per plant	Total length of leaves per plant (cm)	width of leaves (cm)	No. of lesions per		Length of lesions (cm)
Regulated	Range of fluctuation								plant	1 cm of leaf length	
14-20	9-23	77-95	30	37.6	1.0	3.9	63.4	0.52	5.10	0.090	0.44
22-27	22-29	67-91	25	41.7	1.0	4.1	57.8	0.46	1.70	0.029	0.38
27-29	26-30	65-90	20	34.7	1.0	3.3	45.5	0.29	1.40	0.031	0.34
30-32	29-33	58-72	15	26.7	1.0	3.0	25.5	0.23	0.82	0.032	0.31

Sowing: Nov. 20(30-day seedlings), Nov.25(25-day seedlings), Nov.30(20-day seedlings), Dec.5(15-day seedlings). Inoculation: Dec. 20, 1942.

The same tendency was also noticed in the inoculation experiment with the 21-day seedlings which had been sown simultaneously but treated under different temperatures for varied length of time so as to make them attain to approximately the same phase of growth.

Table 26. The results of the inoculation experiment with the 21-day seedlings kept at different temperatures for different periods.

Air tcmp. °C		Days treated	Plant height (cm)	No. of tillers per plant	No. of leaves per plant	Total length of leaves (cm)	width of leaves (cm)	No. of lesions per 1 cm of leaf length	Length of lesions (cm)
Regulated	Range of fluctuation								
19-21	17-26	17	40.5	1.0	4.0	42.5	0.40	0.101	0.51
20-24	18-28	14	40.1	1.0	4.0	54.0	0.44	0.027	0.35
27-29	26-32	11	38.9	1.0	4.0	53.0	0.44	0.015	0.31
31-33	30-33	8	35.7	1.0	4.0	47.2	0.40	0.013	0.29

Sowing:Feb. 24, 1943. Inoculation: Mar. 17, 1943.

The similar result was also obtainted in the experiment when inoculation was made on the seedlings previously grown at different air temperatures for the same period.

Table 27. The results of the inoculation experiment with the seedlings grown at different air temperatures for the same period.

Air temp. °C		Humidity (%)	Growth duration (Days)	Plant height (cm)	No of tillers per plant	No.of leaves per plant	Total length of leaves (cm)	Width of leaves (cm)	No.of lesions per 1 c m of leafleng.	Lteng-lh of esions (cm)
Regulated	Range of fluctuation									
14-20	10-29	75-95	30	40.9	1.0	4.0	66.9	0.53	0.114	0.42
22-27	20-30	70-90	30	48.9	1.0	5.0	90.2	0.58	0.038	0.31
27-29	26-35	66-90	30	45.4	1.0	5.1	92.8	0.58	0.019	0.30
30-32	30-36	50-80	30	48.0	1.0	5.6	97.7	0.53	0.023	0.31

Sowing : Nov.20,1942. Inoculation: Dec.20, 1942.

As will be seen in the following three tables. the same is true of the results of any experiment conducted by use of different varieties.

Table 28. Results of the inoculation experiment with the 28-day seedlings of Taichu Sp. No.6 (a selection of the Japanese variety"Asahi") growng under different air temperatures.

Air temq.°C		Plant height (cm)	No.of tillers per plant	No.of leaves per plant	Total leng-th of leavas (cm)	Width of lea-ves (cm)	No. of lesions per	
Regu lated	Range of flu-ctua-tion						Plant	1 cm.of leaf length
15-18	13-26	48.9	2.2	6.6	92.7	0.56	7.03	0.076
17-20	17-29	49.9	1.0	5.7	85.2	0.52	1.07	0.013
26-28	25-31	53.2	1.0	5.7	100.8	0.55	0.37	0.004
31-33	30-34	45.7	1.0	5.9	105.4	0.55	0.32	0.003

Sowing: Feb.12,1943. Inoculation: Mar.12, 1943.

Table 29. Results of the inoculation experiment with the 25-day seedlings of Taichu No. 150(NC No. 4(an unknown Italian variety x an unknown Japanese variety) x Taichu No. 65) grown under different air temperatures

Air temp. °C		Height of seed-lings (cm)	No.of tillers per plant	No.of leaves per plant	width of lea-ves (cm)	Total length of lea-ves (cm)	No. of lesions per	
Regu-lated	Range of flu-ctua-tion						plant	1 cm of leaf length
15-18	13-26	45.0	1.0	4.0	0.50	76.3	4.31	0.056
17-20	17-29	45.5	1.0	4.4	0.47	71.7	1.34	0.019
26-28	25-31	48.6	1.0	4.6	0 48	81.7	0.87	0.011
31-33	30-34	51.0	1.0	4.6	0.54	87.0	0.92	0.011

Sowing: Feb.16, 1943. Inoculation: Mar.13, 1943.

Table 30. Results of the inoculation experiment with the 25-day seedlings of Taichu GI. No. 46(Taichu No. 65 x { (Omach x Zeng-tou-uh-rwan-tzu) x Taichu Sp.No.2) } grown under different air temperatures.

Air temp. °C		Height of seed-lings (cm)	No. of tillers per plant	No. of leaves per plant	Total length of lea-ves (cm)	width of lea-ves (cm)	No. of lesion per	
Regu-lated	Range of flu-ctuation						Plant	1 cm of leaf length
15-18	13-26	39.9	1.0	4.0	58.5	0.46	8.67	0.148
17-20	17-29	39.6	1.0	4.8	65.7	0.44	2.01	0.031
26-28	25-31	43.9	1.0	4.5	67.3	0.44	1.50	0.022
31-33	30-34	41.9	1 0	4.4	71.0	0.54	1.34	0.019

Sowing: Feb. 16, 1943. Inoculation: Mar. 13, 1943.

Further experiments were carried out by inoculating the seedlings which had been kept under the cool condition (regulated at 17C°. though lfuctuated from 16 ot 26C°) or the warmone (regulated at 28C°. though

fluctuated from 28 to 35°C) at intervals of 5 days in the course of 30-day treatment.

Table 31. Results of the inoculation experiment with the seedlings grown under different air temperatures for every five days.

Within 30 days treated				Height of plant (cm)	No. of tillers per plant	No. of leaves per plant	Total length of leaves (cm)	width of leaves (cm)	No of lesions per	
1 - 10th	11- 15th	16- 20th	21- 30th						plant	1 cm of leaf length
L※	L	L	L	44.5	1.0	4.0	74.8	0.57	4.32	0.058
L	L	L	H	43.1	1.0	4.0	75.6	0.53	2.00	0.026
L	L	H	H	41.6	1.0	4.0	78.7	0.43	1.35	0.017
L	H	H	H	44.3	1.0	4.3	83.2	0.47	0.60	0.007
H	L	L	L	47.0	1.0	4.3	95.0	0.70	18.60	0.196
H	H	L	L	47.5	1.0	4.3	101.7	0.73	6,15	0.060
H	H	H	L	43.3	1.0	4.3	84.3	0.63	1.92	0.023
H	H	H	H	46.6	1.0	5.3	108.4	0.67	2 62	0.024

※ L - Low temperature; H - High temperature.

Sowing: Nov.30, 1942. the opening day of the treatment: Dec.5,1942. Inoculation: Jan.4, 1943.

as seen in the above table, the seedlings grown under the cool condition throughout the whole growth duration were more susceptible than those kept warmer during the whole period or a term just before inoculatiou.

B. Relation of Soil Temperature to the Resistance of the Leaves

Inoculation was made on the plants which had been kept at different soil temperatures during the growth period up to the early stage of tillering.

Table 32. Results of the inoculation experiment with 30 - day seedlings grown at different soil temperatures.

soil temp.°C		Height of plant (cm)	No. of tillers per plant	No. of leaves per plant	Total length of leaves (cm)	width of leaves (cm)	No. of lesions per		length of lesions (cm)
Regulated	Range of fluctuat						plant	1 cm of leaf length	
16-19	16-23	35.4	2.8	8.8	99.5	0.63	13.00	0.131	0.50
20-22	19-26	44.6	2.9	9.5	130.2	0.75	9.92	0.076	0.55
21-23	20-29	45.4	2.9	9.8	126.9	0.80	9.88	0.077	0.50
24-25	24-30	45.0	2.9	9.3	141.6	0.80	10.25	0.072	0.58
28-29	27-30	46.7	2.8	9.3	147.1	0.83	10.32	0.070	0.55
30-31	30-34	46 0	2.5	10.5	151.8	0.78	5.28	0.034	0.53
32-34	31-35	42.4	2.3	9.0	117.3	0.77	10.00	0.085	0.55

The opening day of the treatment: Dec. 28, 1942. Inoculation: Jan.27, 1943.

The air temperatures during treatment: 12-26°C.

The results of the above experiments showed the same tendency as noticed in the experiment of air temperature, though less striking in difference between each temperature as compared with the latter. This might be probably due to the effect of the air temperature which is almost the same in spite of the difference in soil temperature.

C. Relation of Air Temperature to the Resistance of the Ears

In the next experiment the rice plants kept at different temperatures during booting as well as heading were employed, inoculation being made on their ears after the heading had completed.

Table 33. Results of the inoculation experiment on the ear of the plants raised under different conditions of air temperature.

Air Temp. °C		No. of ears employed	Duration of treatment		Percentage of infect.	
Regulated	Range of fluctuat.		whole duration of heading	Culmination of heading	Necks	Ears
18-20	15-25	720	24 / XII - 6 / I	31 / XII - 4 / I	39.84	82.03
30	26-33	530	24 / XII - 3 / I	30 / XII	2.22	51.11

The results of the above experiment showed the same tendency as in the case of the leaves, but the former is considered to be due to disease escaping, since the ears as well as the necks developed under a warm condition ·become resistant anatomically as well as physiologically somewhat earlier then those under the cool weather on account of the rapid development of their ears and necks.

D. Relation of Air Temperature to the Resistance of the Rice Seedlings Grown under Different Nutritional Conditions

As regards the effect of temperature on the resistance of plants grown under different nutritional conditions, studies are rather limited, so far as the author is aware. Jewett (1938) pointed out that tobacco plants grown at the lower soil temperatures (18-20°C) was more susceptible to *Thielavia basicola* than those at the higher (28-30°C) regardless of the presence or absence of nitrates. In the present investigation inoculation was made in the first place on the seedlengs supplied with a single element (300 kg. per ha., table 34) or two elements, in the latter case 160 kg., 120kg., and 100 kg. of N, P_2O_5 and K_2O, respectively being given.

Table 34. Results of the inoculation experiment with the seedlings supplied with a single element of fertilizer and grown at different air temperatures for 28 days.

Fertilizer given	Air temper. (°C)	Height of plant (cm)	No. of tillers	No. of leaves	Total length of leaves (cm)	Width of leaves (cm)	Colour of leaves ※	External appearance ※※	Length of roots (cm)	Colour of roots ※※※	No. of lesions Per Plant	No. of lesions Per 1 cm of leaf length
N alone	Low	30.7	3.0	7.4	75.9	0.62	++++	Soft	11.3	+	3.54	0.047
	Opt.	48.3	2.2	7.2	96.9	0 68	+++	S.soft	12.2	+++	2.40	0.025
	High	29.4	1.8	6.0	73.2	0.66	+++	S.rig.	9.2	+++	2.50	0.034
P_2O_5 alone	Low	27.5	1.0	4.2	36.6	0.42	+++	S.soft.	15.0	+	0.06	0.002
	Opt.	40.5	1.0	4.4	67.9	0.58	+	S.rig.	16 9	++	0.09	0.001
	High	25.9	1.0	6.0	50.4	0.58	++	Rigid	10.9	+++	0.14	0.003
K_2O alone	Low	28.3	1.6	5.0	41.6	0.40	+++	S.soft	18.0	++	0.06	0.001
	Opt.	38.8	1.0	4.0	63.9	0.60	+	Rigid	19.5	+++	0.06	0.001
	High	29.9	1.0	4.2	56.7	0.54	++	Rigid	16.6	++++	0.09	0.002

Air temperetures: Low 14 - 20°C, opt. 25 - 29°C, high 30 - 32°C.

※The number of + means the depth of leaf colour.※※ S. soft - somewhat soft; S. rig. - somewhat rigid. ※※※+ means white, ++++ means brown, and the other mean the different grade of colour between the two above--named.

Table 35. Results of the inoculation experiment with the seedlings supplied with two elements of fertilizer and grown at different air temperatures for 28 days, excepting those at the low temperature, which were grown for 33 days.

Fert-tilizer given	Air Temp.	Hei-ght of plant (cm)	No. of til-lers	No. of lea-ves	Total leng-th of lea-ves (cm)	Width of leaves (cm)	Colour of leaves	Exter-nal appea-rance	Leng-th of roots (cm)	Colour of roots	No. of lesions	
											Per Plant	Per 1 cm of leaf length
3 ele-ments	Low	19.9	1.0	3.4	36.1	0.40	+	Rigid	18.0	++++	0.049	0.001
defici	Opt.	28.6	1.0	3.4	44.2	0.34	+	Rigid	21.1	++++	0.026	Trace
ency	High	26.1	1.0	3.8	48.0	0.40	+	Rigid	17.4	++++	0.105	0.002
N de-fici-	Low	19.1	1.0	3.2	34.7	0.24	+	Rigid	14.3	+++	0.010	Trace
	Opt.	29.2	1.0	3.6	46.8	0.36	+	Rigid	13.8	+++	0.010	Trace
ency	High	26.7	1.0	3.4	44.4	0.36	+	Rigid	12.5	++++	0.027	Trace
P_2O_5	Low	37.4	2.4	9.2	108.0	0.58	+++	S. soft	13.3	++	1.703	0.016
defici-	Opt.	42.6	1.4	5.2	82.5	0.62	+++	S. soft	14.7	++	0.449	0.005
ency	High	42.6	1.0	4.8	86.3	0.60	++	S. rig.	15.0	+++	1.079	0.012
K_2O	Low	36.6	2.8	9.8	108.8	0.64	+++	S. soft	13.2	++	1.809	0.017
defici-	Opt.	49.0	2.6	10.4	113.1	0.60	+++	S. soft	12.1	++	0.875	0.008
ency	High	43.0	2.0	8.4	104.6	0.64	++	S. soft	13.0	+++	0.465	0.004
3 ele-ments	Low	36.6	2.8	10.8	131.0	0.54	+++	soft	13.9	+	3.460	0.026
	Opt.	50.4	1.6	6.0	126.5	0 64	+++	S. soft	14.0	+	0.765	0.006
suffici-ency	High	48.1	1.8	8.4	122.0	0.64	++	S. soft	13.0	+	1.065	0.008

Air temperature: Low 13 - 21°C, opt. 24 - 27°C, high 28 - 31°C.

Table 36. Results of the inoculation experiment with the seedlings grown for 25 days under the different conditions of air temperature and nutrition.

Fer-tili-zer given	Air temp.	Hei-ght of plant (cm)	No. of til-lers	No. of lea-ves	Total leng-th of leaves (cm)	Width of lea-ves (cm)	Col-our of lea-ves	Exter-nal ap-pea-rance	Leng-th of roots (cm)	Col-our of roots	No.of lesions	
											per plant	Per 1 cm of leaf length
Non-man.	Low	29.6	1.0	4.0	47.1	0.46	+	Rigid	17.8	+++	0.35	0.007
	Opt.	35.0	1.0	4.0	58.2	0.50	+	Rigid	17.3	+++	0.50	0.009
	High	27.0	1.0	4.2	47.8	0.42	+	Rigid	16.1	++++	1.00	0.021
Pro-per man.	Low	46.3	1.2	5.0	72.3	0.64	+++	S.soft	12.2	+	12.00	0.163
	Opt.	56.1	1.2	5.6	101.6	0.66	+++	S.soft	12.8	+	7.00	0.069
	High	34.1	1.0	5.6	72.2	0.30	++	Rigid	16.4	++	3.80	0.053
Exce-ssive man.	Low	42.9	1.8	6.4	72.5	0.68	++++	S.soft	13.8	++	16.32	0.225
	Opt.	51.7	1.0	5.0	99.5	0.68	++++	Soft	13.1	+	9.01	0.091
	High	36.7	1.0	5.2	73.7	0.58	++++	Rigid	7.0	++	4.31	0.058

Air temperature: Low 18 - 26°C, opt 26 - 31°C, high 32 - 34°C.

Furthermore, studies were made with the use of fertilizers different in quality as well as in quantity. The results are shown in tables 37 - 39.

Table 37. Results of the first inoculation experiment with variously fertilized seedlings grown at different tempertures for 22 days.

Fertilizer given	Amount (Kg.per ha.)			Air temp	Height of seedling (cm)	No.of tillers	No.of leaves	No.of lesions per plant
	N	P_2O_5	K_2O					
Proper amount of 3 elements	80	60	50	Low.	38.6	1.0	3.34	10.80
				Opt.	47.9	1.0	4.46	4·15
				High	47.1	1.0	4.59	3.08
Excess of N	240	60	50	Low	41.0	1.0	4.02	11.10
				Opt.	44.2	1.0	4.14	3.43
				High	35.9	1.0	3.38	2.22
Excess of P_2O_5	80	180	50	Low	41.9	1.0	3.32	9.47
				Opt.	49.8	1.0	4.60	4.09
				High	45.0	1.0	4.44	1.88
Excess of K_2O	80	60	150	Low	41.9	1.0	3.82	8.49
				Opt.	49.8	1.0	4.36	3 56
				High	43.6	1.0	4.49	2.36
Excess of 3 elments	240	180	150	Low	41.4	1.0	3.51	10.90
				Opt.	49.5	1.0	4.22	4.37
				High.	43.6	1.0	4.16	3.05

Air temperature: Low 17 - 26 °C, opt. 25 - 30°C, high 28 - 33°C.

Inoculation experiments were also conducted with the seedlings fertilized in various ways other than the above-named, viz. non-manuring, proper manuring (N 80 kg., P_2O_5 60kg., K_2O 50 kg. per ha.) and excessive manuring (three times as much as the proper manuring).

Table 38. Results of the the second inoculation experiment with variously fertilized seedlings grown at different air temperatures for 20 days.

Fertilizer given	Amount (Kg. per ha.)			Air temp.	Height of plant	No. of tillers	No. of ivea-es	Total length of leaves (cm)	Width of leaves (cm)	No. of lesions	
	N	P_2O_5	O5k2							Per plant	Per 1 cm of leaf length
A little of 3 elements	40	30	25	Low	40.0	1.0	4.2	72.1	0.62	6.18	0.086
				Opt.	46.6	1.0	4.6	87.0	0.56	2.15	0.025
				High	37.7	1.0	5.2	82.1	0.52	0.20	0.002
Excess of N	160	30	25	Low	47.5	1.5	5.6	94.3	0.58	5.73	0.061
				Opt.	48.3	1.0	5.0	106.3	0.60	0.42	0.004
				High	49.2	1.0	5.2	91.4	0.54	0.51	0.006
Excess of P_2O_5	40	120	25	Low	40.2	1.0	4.9	82.7	0.66	4.59	0.056
				Opt.	49.7	1.0	5.4	101.2	0.71	1.70	0.017
				High	39.0	1.0	5.0	89.5	0.56	0.34	0.004
Excess of K_2O	40	30	100	Low	34.9	1.0	5.2	71.8	0.74	5.66	0.079
				Opt.	43.5	1.0	5.0	89.3	0.60	1.90	0.021
				High	39.2	1.0	5.2	87.7	0.60	0.15	0.002
Excess of 3 elements	160	120	001	Low	40.8	1.3	7.0	99.6	0.64	7.70	0.077
				Opt.	47.9	1.0	5.0	91.1	0.68	1.62	0.018
				High	36.2	1.0	5.6	74.2	0.52	0.16	0.002

Air Temperature: Low 22 - 27°C, opt. 28 - 33°C, high 30 - 33°C.

Table 39. Results of the third inoculation experiment with variously fertilized seedlings grown at different air temperatures for 25 days.

Fertilizer given	Amount (Kg. per ha.) N	P_2O_5	K_2O	Air temp.	Height of plant (cm)	No. of tillers	No. of leaves	Total length of leaves (cm)	width of leaves (cm)	Colour of leaves	No of lesions Per plant	Per 1 cm of leaf length
A little of 3 elements	40	30	25	Low	44.2	1.2	5.0	82.3	0.70	++	7.25	0.088
				Opt.	45.7	1.0	5.0	88.5	0.64	+++	2.84	0.032
				High	43.9	1.0	4.8	95.3	0.62	++++	2.40	0.025
Excess of N	160	30	25	Low	40.5	1.2	5.2	94.3	0.70	++++	7.30	0.077
				Opt.	47.0	1.0	4.8	92.8	0.76	++++	4.10	0.045
				High	41.9	1.0	5.0	86.2	0.62	++++	1.43	0.017
Excess of P_2O_5	40	120	25	Low	43.2	1.0	4.6	85.5	0.66	++	5.76	0 067
				Opt.	44.3	1.0	4.6	94.9	0.78	++	3.40	0.036
				High	44.3	1.0	4.6	98.2	0.70	+++	2.97	0.030
Excess of K_2O	40	30	100	Low	42.8	1.0	5.0	84.7	0.64	+	4.85	0.057
				Opt.	43.8	1.0	4.2	84.5	0.64	+	1.30	0.015
				High	44.8	1.0	4.0	84.6	0.62	++	0.80	0 009
Excess of 3 elements	160	120	100	Low	43.6	1.2	5.0	83.5	0.74	++++	5.94	0.071
				Opt.	50.1	1.0	4.8	95.5	0.76	++++	4.10	0.043
				High	46.0	1.0	4.8	91.7	0.72	++++	4.03	0.044

Air temperature: Low 24 - 32 °C, opt, 29 - 33 °C, high 30 - 34 °C,

As seen in the above tables, the disease occurred more severely on the plants grown under the cooler conditions than on those under the higher ones. It is to be remembered, however, that at the optimum or high temperatures the result has not always been clear-cut, and in some cases it has been rather opposite to the above-named. In general, the effects of temperature on the resistance of the rice seedlings appear to be somewhat interdependent on the nutritional conditions. It has been confirmed by the author that the rice seedlings tend to become susceptible when supplied with nitrogen, and become slightly and highly resistant at the presence of phosphoric acid and potash, respectively. In the case of N-supply the seedlings grow luxuriantly with soft, dark green leaves and abundant white roots, but in the deficiency of it they are contrary to the above,

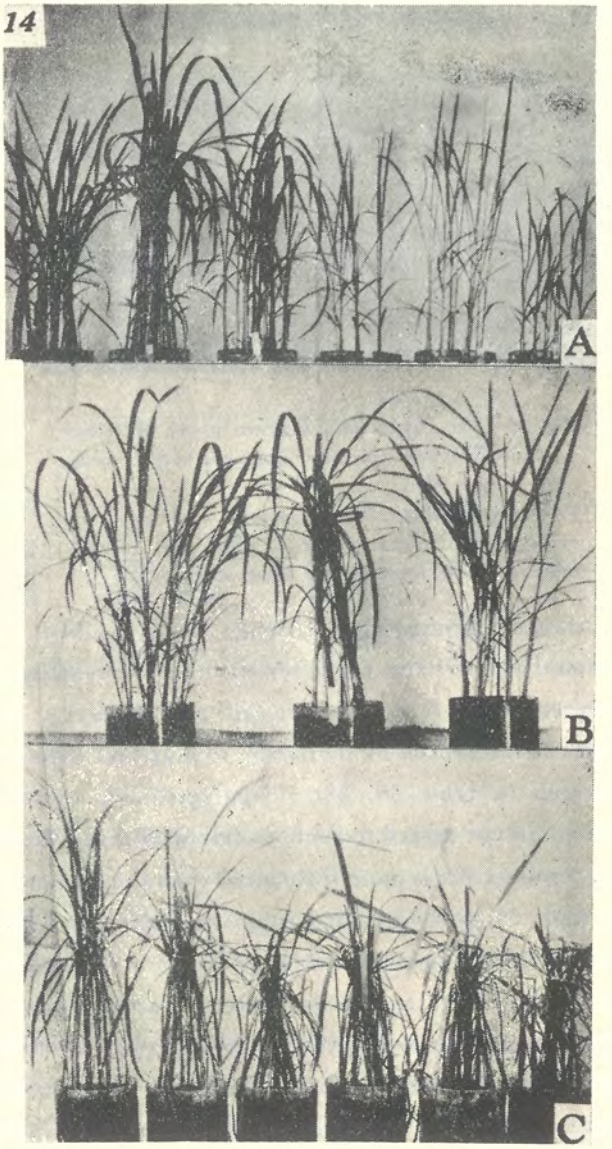


Fig. 14. The rice seedlings grown under the different conditions of air temperature and nutrition.

(A) The seedlings in the experiment of table 36. The three left - Moderately manured seedlings (from left to right; high, Opt. low, respectively) The three right - Non - manured seedlings (do.)

(B) The seedlings in the experiment of table 36. The seed lings ex cessively Manured with 3 ele ments (from left to right: Low, opt. & high, respectively)

(C) The seedlings in the experiment of table 37. The three left - The seedlings excessively manured with potash (frmo left to right: high, Opt. & low respectively; The three right - The seedlings excessively manured with 3 elements (do).

Fig. 15 The rice seedlings grown under diffrerent sunshine durations (The plants employed in the experiment of table 56).
From left to right: 24-hour-exposure, whole daytime-exposure, half day-exposure to direct and diffused lights, 8.5-hour- exposure half day-exposure.

appearing as if they are lacking in all essential elements. Regardless of the quality and quantity of the fertilizers given, however, the seedlings have a tendency to become more straight, rigid, resistant, and lighter in colour in proportion to warmness in approximately the same manner as in thecase of nitrogen deficiency (*vide.* fig.14). As to the retion of the amount of fertilizers to the resistance of the seedlings grown at different air temperatures, it was confirmed that under a certain condition resistance is influenced by manuring to a greater extent than by temperature as seen in table 36, but if the fertilizer is given at the concentrations which do not exceed to such an extent as make the plants grow abnormally, temperature is more influential than the former. For instance, as shown in table 36, when a comparison is made between the seedlings which are grown equally at a certain lower temperature but fertilized at varied concentration, their susceptibility is increased in proportion to the amount of fertilizers given, but if the seedlings grown at different temperatures are compared, those at the higher temperature are proved to be more resistant than those at the lower, even if the former are cultured with excess of nitrogen or fertilized more abundantly than the latter. Furthermore, under the higher temperature conditions resistance-susceptibility relation is not always changed in parallel with the amount of fertilizers. In other worsd,

when the seedlings are grown under the warmer conditions, they become equally more resistant regardless of the amount of nitrogen as compared with those under the cooler conditions and supplied with surplus of potash. Further it is worthy to note that the seedlings grown under the conditions of either N-deficiency or lack of all the three elements are somewhat more susceptible at the higher temperatures than those at the lower (*vide.* tables 34 -- 36), and that this fact is in accord with the results of the chemical analysis of these seedlings which will be mentioned later. From these results hitherto mentioned, it is concluded that the resistance to the blast disease of the leaves of the rice plants is enhanced in proportion to the increase of air - and soil temperature regardless of the difference in age, variety, and fertilization with the exception of the temperatures higher than the optimum for the plant growth (ca.28°C, according to the author's experiment), in which case they sometimes become slightly more susceptible. By the reason mentioned above, it is to be remembered that the temperature condition has an important meaning upon the relation of manuring to the resistance of the rice plants. Abe (1933,*b*) and Hemmi & Abe (1932) pointed out that rice seedlings became most resistant and stout when they were grown at the soil temperature of 28°C, although they were inferior in height to those at 32°C. The same was also true with the author's experiments, though the grade of resistance at the temperatures higher than the optimum for the seedlings was not always in accord with the results of the above-named workers.

As regards the optimum air temperature for the growth of the rice seedlings the author determined it to be 28°C. Prior to this, Ocfemia (1924) reported that the optimum for the germination of rice seeds (certain Philippine upland and lowland varieties) was 28 - 32°C. This was also supported by Abe (1933,*b*) who studied on the Japanese varieties. Sasaki (1927) reported that the elongation of leaves of rice plants was most active at the air temperature of 30 - 31°C. Tojyo (1930) and Kikkawa (1930) also pointed out that the rice seedlings grew most vigorously when the soil and water were 32°C. Kondo & Okamura

(1930,1931) concluded from the extensive studies on the relation of water temperature to the plant growth that the optimum for elongation of leaves, tillering, total weight of plants, weight of straws and weight of grains were 30 - 32°C, 32 - 34°C, 30 - 34°C, 32°C and 30°C, respectively. Abe (1933,*b*) further stated that the seedlings grew more vigorously at the soil temperature of 28°C than at 32°C, thongh the elongation of the leaves was better at the latter. Nishikado & Nakayama (1943) also confirmed that the soil temperature optimum for the elongation of rice seedlings is 28 - 31°C. Comparing the studies mentioned above, it seems that the result of the present author's is somewhat lower than that of the others'. In all probability this difference may be due to the difference of the experimental procedure and not to the difference of the varieties employed nor to other causes. Namely in most of the experiments other than the present auther's, the aerial parts of the plants were all exposed to the same cool air without discrimination, since those experiments were carried out during the cold season in order to make the soil and water constant at any required temperatures. Under natural conditions, air temperatures change almost in parallel to soil- and water tempetatures (*vide*.chapt.11, sect.2), and are by no means so different from the others as noticed in the experiments of the above-named authors. It is of no doubt that the optimum temperature of the author was somewhat lower than that of the previous workers, since in the author's experiments the temperatures of the soil and water differ not so much from those of the air as compared with the results of the previous workers'. In view of the facts mentioned above, the results of the author's experiments are considered to be more reasonable than those of the others for interpreting the natural phenomena, espeeially in the subtropical regions. It is to be remembered, however, that the optimum temperature mentioned above is mainly concerned with the growth of the seedlings up to the tillering stage, since the author's experiments have been confined to the disease of the leaves.

E. The Role of Temperature as a Cause of Resistance of Rice Plants and of Prevalence of the Disease

Considering the relation of soil temperature to various plant disease. Jones, Johnson & Dickson (1926) concluded that the plant diseases employed for their experiments can be generally divided into the following three classes according to the temperature relation, *viz.*, (1) the disease occuring seriously at rather higher temperatures, (2) those at rather lower temperatures, (3) those which are different in the optimum temperatures for the disease development as the hosts differ. In the first group, the relation of temperature to the host resistance is almost negligible, since the optimum temperature for the outbreak of the disease generally coincides with that for the growth of the parasite, as seen in the diseases caused by the vascular parasites, such as *Fusaria*. In the second group, the resistance of the hosts has an important bearing upon the development of the disease as seen in onion smut, tobacco root rot, potato stem canker, etc., since in this case the disease is often avoided by the rapid growth of the host plants (*i.e.* disease escaping) or other complicated host-parasite relations. The third group is represented by the well-known example of the *Fusarium* (*Gibberella*) seedling blight of wheat and corn studied by Dickson (1923). In this case the disease hardly occurs at the optimum temperature for the growth of the host plants owing to the promotion of the host resistance, namely, the host resistance is primarily important for the outbreak of this disease. A somewhat similar relation is also noticed by Mckinney (1923) on take-all of wheat and barley seedlings (*Helminthosporium sativum*). by Ocfemia (1924) on seedling blight of rice (*Helminthosporium oryzae*), and by Hemmi & Abe (1932) and Abe (1933,*b*) on rice seedling blast (*Piricularia oryzae*). According to them, on the "low-temperature" cereals, i.e. wheat and barley, the severest infection by the first-named fungus occurs at 28 - 32°*C* which is distinctly higher than the optimum for both the parasite and host, while on the "high-temperature" plants, i.e. rice, the seedling blights caused by *H. oryzae* and *P. oryzae* occur seriously at 16 - 20°C (the lowest of the temperature gradations tested), respectively, and cease to spread at 28°C and above, notwithstanding the fact that the rice plant grow well at the temperatures higher than 30°C, and the parasites are equally most vigorous at 28°C which is higher

than the optimum for the growth of the northern fungus. *H. sativum*. In the author's opinion, however, the second- and third groups divided by Jones *et al.* are not always distinguished clearly *inter se*. Recently, Leach (1947) studied on the pathogenicity of several damping-off fungi to different host at different soil temperatures and reached to the conclusion that "upon the same host several specific organisms show different temperature ranges for infection" and likewise "a single organism may have different optimum temperature range for infection of different hosts". In his experiments, the severity of preemergence damping-off is agreed closely with the ratio between the coefficient of velocity of emergence which was proposed by him and the growth rate of the parasite at the same temperature, and in general, infection was severest at temperatures relatively less favourable for the host than for the pathogen. The second and third categories of Jones *et al.* are combined in Leach's conclusion. The same was the case of the author's study (Hashioka,1944) on the polyxenous fungus, *Corticium* (*Hypochnus*) *Sasakii*. On the other hand, Cassner & Franke (1934) confirmed that the wheat seedlings grown at different temperatures were distinctly different in their rust resistance as well as in their biochemical natures when inoculation was made at the same time on the seedlings which attained the similar phase of growth in their external appearance. In this case, the resistance is considered to be caused by the substantial change of the internal physiology and not explained by the "escaping" in the ordinary sense, since the plants were different in growth period (age) which is prolonged in proportion to coolness, e.g. the seedlings were grown at different temperatures for varied length of time so as to make them attain the same phase of growth. Hence, in this case the outbreak of the disease is swayed by the host resistance.

As to the cause of resistance effected by temperature, Dickson & Holbert(1928) pointed out that, under the soil temperature unsuitable for the growth of the host plants, the cell membrane of the host cells are not able to develop normally, and nitrogenous compounds suitable for the parasite, such as asparagin, are accumulated due to decrease of soluble

carbohydrates as well as increase of soluble nitrogen. By comparing the chemical content of the wheat seedlings grown at different air temperatures (5,10 and 20°C), Gassner & Franke (*loc.cit.*) found that the dry weight and the proteinous nitrogen increased sharply with decrease of temperature, while the soluble nitrogen showed no distinct difference. Consisdering these evidences as well as those given by the previous studies (Gassner & Straib, 1929, 1931) which show that wheat seedlings increase susceptibility to the rusts when grown at low temperatures, they concluded that the increase of proteinous nitrogen due to coolness predisposes the susceptibility of the plants. This finding that the content of proteinous compounds in the leaves of the higher plants increases in proportion to coolness is also in harmony with the results obtained by Mothes (1926), Mevius & Engel (1929), etc.

The author intended to study the content of silica as well as nitrogen of the leaves of the rice seedlings employed in the various experiments hitherto mentioned by the microchemical and analytical methods, since it is considered that the change of resistance of the rice-seedlings is rather due to the substantial change of the physiological properties and not merely to the disease escaping. The results of the comparative studies on the number of the silicated epidermal cells of the leaves of the rice seedlings grown under different temperature conditions showed that the silicification of the epidermal cells was in parallel relation to the temperature under which the seedlings were cultured, though this relation was somewhat confused at the temperatures higher than the optimum for the growth of them, as seen in tables 40 - 42.

Table 40. Number of the silicated epidermol cells per unit area of the 4th leaves of the seedlings grown under different air temperatures for 30 days.

Air temperature°C		No. of silicatec cells		
Regulated	Fluctuated	Motor cells	Long & short cells	Stomatal cells
14 - 16	9 - 25	1.31	0.00	0
17 - 20	17 - 25	2.00	0.20	0
25 - 26	23 - 30	6.65	0.65	0
30 - 31	30 - 36	2.85	3.35	0

Table 41, Number of the silicated epidermal cells per uuit area of the 5th leaoves the seedlings of Taichu Sp.No.6 grown under different air temperatures for 33 days.

Air temperature °C		No.of silicated cells		
Regulated	Fluctuated	Motor cells	Long & short cells	Stomatal cells
15 - 18	13 - 26	0.80	0.00	0
17 - 20	17 - 29	3.00	0.00	0
26 - 28	25 - 31	9.50	0.01	0
31 - 33	30 - 34	0.82	0.81	0

The samples of this experiment are the same as those in table 28.

Table 42. Number of the silicated epidermal cells per unit area of the 4th leaves of the seadlings grown under different soil temperatures for 30 days.

Soil temperature °C		No.of silicated cells		
Regulated	Fluctuated	Motor cells	Long & short cells	Stomatal cells
18 - 20	16 - 21	0.03	0	0
20 - 22	19 - 23	2.35	0	0
23 - 24	23 - 25	2.25	0	0
26 - 27	24 - 27	5.50	0	0
29 - 30	29 - 30	10.08	Trace	0
32 - 33	31 - 34	7.55	Trace	0
34 - 35	34 - 36	5.75	Trace	0

The results of the quantitative analysis of the content of total nitrogen and carbohydrate in the leaves of the seedlings grown under different air - and soil temperatures showed that the above substances have also an important relation to resistance-susceptibility of the rice seedlings to the present disease as shown in tables 43 - 46.

Table 43. Content of total nitrogen and carbohydrate in the leaves of the seedlings grown under different air temperatures for 30 days.

Air temperature °C		% (Dry basis)		CN ratio
Regulated	Fluctuated	N	C	
15 - 16	14 - 26	4.35	15.4	3.54
18 - 20	17 - 28	3.92	14.0	3.57
26 - 27	15 - 30	3.43	14.5	4.23
30 - 32	30 - 36	3.60	14.5	4.03

Table 44. Content of total nitrogen and carbohydrate in the leaves of the seedlings grown under different air temperatures for 27 days.

Air Temperature °C		% (Dry basis)		CN ratio
Regulated	Fluctuated	N	C	
15 - 18	13 - 28	4.47	13.00	2.91
18 - 19	17 - 28	4.24	13.35	3.14
26 - 28	26 - 30	3.61	11.11	3.08
32 - 34	31 - 35	2.89	9.78	3.39

Table 45. Content of total nitrogen and carbohydrate in the leaves of the seedlings of Taichu Sp. No.6 grown under different air tempreatures for 33 days.

Air Temperature °C		% (Dry basis)		CN ratio
Regulated	Fluctuated	N	C	
15 - 18	13 - 26	3.80	20.53	5.40
17 - 20	17 - 29	3.56	20.74	5.83
26 - 28	25 - 31	3.11	23.89	7.68
31 - 33	30 - 34	3.14	22.67	7.21

Table 46. Content of total nitrogen and carbohydrate in the leaves of the seedlings grown under different soil temperatures for 30 days.

Soil Temperature °C		% (Dry basis)		CN ratio
Regulated	Fluctuated	N	C	
18 - 20	16 - 21	4.96	12.35	2.49
20 - 22	19 - 23	4.69	13.85	2.95
23 - 24	23 - 25	4.65	13.00	2.80
26 - 27	24 - 27	4.56	13.35	2.93
29 - 30	29 - 30	4.37	14.00	3.20
32 - 33	31 - 34	4.24	14.00	3.30
34 - 35	34 - 36	4.15	14.90	3.59

Furthermore, some other substances relating to resistance-susceptibility of the seedlings supplied with the fertilizers of different quality and quantity at different air temperatures were also studied with the use of the same materials employed in the inoculation experiments already mentioned. The results of the analysis of these substances are shown in tables 47 - 49.

Table 47. The results of the chemical analysis of the plants supplied with a single element at different air temperatures (cf. tab.34).

Manuring	Air temp	Leaf blades and sheaths							Roots		
		Weight (g.) (per plant)		Moist. (%, fresh basis)	% (Dry basis)				Weight (g) (per pl.)		Moist. (%, fresh basis)
		Fresh	Dry		Ash	Total N	Silica	Potash	Fresh	Dry	
N alone	Low	0.550	0.092	83.28	13.46	4.96	4.11	2.79	0.217	0.038	82.49
	Opt.	0.872	0.132	84.87	14.87	4.44	5.57	3.20	0.191	0.024	87.44
	High	0.746	0.159	78.68	13 94	4.42	5.40	2.85	0.392	0.017	95.40
P_2O_5 lone	Low	0.250	0.058	76.80	14.43	2.31	7.66	2.49	0.275	0.050	81.82
	Opt.	0.518	0.091	82.44	17.97	1.78	10.22	2.70	0.300	0.035	88.34
	High	0.468	0.108	76.88	15.19	2.48	8.07	2.59	0.391	0.029	92.32
K_2O alone	Low	0.258	0.058	80.66	13.62	2.87	6.65	2.83	0.200	0.043	78.50
	Opt.	0.441	0.092	79.12	17.16	1.85	9.86	2.52	0.246	0.029	88.62
	High	0.799	0.091	88.60	15.11	2.60	8.53	2.42	0.427	0.029	93.20

Taele 48. The results of the chemical analysis of the seedlings grown under deficiency of one element at different air temperatures (cf. tab. 35).

Manuring	Air temp.	Leaf blades and sheaths							Roots			
		Weight (g.) per plant		Moist. (%, fr. basis)	% (Dry basis)				Weight (g, per plant		Moist. %, fr. basis	Total N
		Fresh	Dry		Ash	Total N	Silica	Potash	Fresh	Dry		
3 elements deficiency	Low	0.212	0.034	83.86	14.05	2.01	8.05	0.94	0.240	0.038	84.17	1.65
	Opt.	0.287	0.050	82.58	14.09	1.56	8.47	1.39	0.242	0.042	82.65	1.63
	High	0.317	0.053	83.28	16.18	1.95	10.02	1.91	0.315	0.042	86.67	1.65
N deficiency	Low	0.207	0.039	81.16	15.18	1.95	9.67	3.77	0.357	0.031	91.31	1.65
	Opt.	0.290	0.049	83.11	15.55	1.73	9.61	2.35	0.205	0.028	86.34	1.65
	High	0.332	0.054	83.74	17.58	1.91	10.70	0.79	0.342	0.032	90.64	1.52
P_2O_5 deficiency	Low	0.903	0.141	84.38	8.96	3.82	2.84	1.89	0.454	0.055	87.87	1.95
	Opt.	0.890	0.123	86.18	10.94	3.90	5.15	2.30	0.279	0.037	86.74	1.91
	High	0.765	0.122	84.05	12.18	3.64	6.51	0.55	0.395	0.051	87.09	2.04
K_2O deficiency	Low	1.200	0.213	82.25	6.18	3.56	1.96	0.56	0.592	0.067	88.68	1.78
	Opt.	1.276	0.160	87.46	9.79	3.47	4.97	1.70	0.430	0.071	83.49	1.67
	High	1.040	0.160	84.61	10.77	3.38	5.26	1.08	0.302	0.050	83.45	2.13
Sufficient 3 elements	Low	1.437	0.218	84.83	9.97	3.30	2.43	1.62	0.646	0.070	89.15	2.21
	Opt.	1.360	0.151	98.90	10.33	3·64	3.43	2.32	0.334	0.057	82.94	1.91
	High	1.068	0.162	84.83	12.28	3.99	4.57	2.16	0.314	0.044	85.99	2.26

Table 49. The results of the chemical analysis of the seedlings grown with different amount of fertilizers at different air temperatures (cf. tab. 36).

manuring	Air temp.	Leaf blades and sheaths							Roots		
		weight (g). per plant		Moist. (%, fr. Basis)	% (Dry basis)				Wight (g). per plant		Moist. (%, fr. basis)
		Fresh	Dry		Ash	Total N	Silica	Potash	Fresh	Dry	
Non-manuring	Low	0.250	0.046	92.19	17.78	2.62	10.27	3.08	0.115	0.021	81.74
	Opt.	0.370	0.065	86.87	20.53	2.71	14.54	2.81	0.131	0.026	80.14
	High	0.428	0.061	85.36	22.83	2.84	14.74	1.26	0.112	0.022	80.36
Moderate Nanuring	Low	0.724	0.115	83.90	14.62	4.28	5.32	3.34	0.296	0.031	89.51
	Opt.	0.895	0.134	85.09	17.15	4.15	3.97	3.72	0.215	0.021	90.23
	High	0.775	0.125	84.20	17.49	3.63	8.02	3.59	0.250	0.028	88.80
Excessive Manuring	Low	0.840	0.123	85.75	14.63	4.56	5.05	2.80	0.252	0.026	89.66
	Opt.	0.806	0.105	82.50	17.16	4.65	6.87	3.19	0.115	0.018	84.35
	High	1.075	0.084	81.60	16.98	4.35	8·30	3.09	0.175	0.019	88.14

The results of the above tables are summarized as follows: The fresh weight, dry weiyht and moisture content of the leaves and roots are in proportion to the amount of fertilizers given, especially that of nitrogen, and, on the whole, they are larger at the optimum to low temperatures inclusive. On the other hand, in the case of deficiency of nitrogen or all the elements, they are contrary to the above. The content of ash and silica is higher in the plants deficient in nitrogen or all fertilizers, and decreases by supply of nitrogen. Regardless of the quantity and quality of the fertilizers given, these substances increase in proportion to warmness except at the higher temperatures above the optimum at which they tend to decrease. This tendency is especially clear in the silica content, being in accordance with the case of microchemical tests already mentioned. On the contrary, the content of total nitrogen increases in proportion to the amount of nitrogen and also to coolness. It is to be remembered, however, that the amount of nitrogen in the leaves of the seedlings grown under the deficiency of nitrogen or all elements is somewhat larger at the higher temperatures, being in accordance with the results of the inoculation experiments already stated. The amount of potash seems to be somewhat related to resistance by the reason that it is smaller in the case of deficiency of potash as well as of all the elements, and in most cases it is

largest at the optimum temperature, but, on the whole, this is of rather minor importance as a cause of resistance in comparison with that of silica, since this substance is rather variable according to the environmental conditions except for the cases mentioned above.

From these results the following conclusion may be gained. Regardless of the age and variety of plants as well as the quality and quantity of the fertilizers under the nitrogen content increases with decreases of temperature, but, on the contrary, the carbohydrate content is increased in proportion to warmness and also in parallel with resistance. Silica is quite opposite to nitrogen. These facts support the theory of Akimoto (1939) that SiO_2/N may be an indicator of resistance-susceptibility of the rice plants to the blast disease. Furthermere, Suzuki (1943,*a*,*b*) pointed out by comparing the content of K_2CO_3 and NH_4Cl in the rice plants that K-NH_4 ratio is also very important as an indicator in the sense mentioned above. But according to the author's experiments, as has already been stated, the content of potash does not seem to be much important as a controlling factor. In conclusion, it may be said that under cooler conditions the rice plants tend to become susceptible due to accumulation of nitrogen and deficiency of silica and potash in their bodies, but at the higher temperatures the effect is quite opposite to the above.

As early as 1915, Suzuki & Ogata reported from Formosa that the content of nitrogen in the grains and straws of the rice plants is more abundant in the 1st crop than in the 2nd one, especially in the case of nitrogen deficiency, the amount of the nitrogen content in the 2nd crop is only 69 per cent of the other. Iso & Moriyama (1934), also working in the same place, reported that the CN ratio of the rice plants was increased in the 2nd crop more extensively than in the 1st. Enomoto (1941) also pointed out that the CN ratio of the rice plants is lower when they are irrigated with cool water than when with warm one. According to the comparative studies of Kuno (1937) on the chemical constituent of the straws of rice plants growing in northern and southern Korea, the temperature of the former being 6° C higher than that of the latter throughout the all growing season, the straws from the northern Korea contain a larger amount of

total nitrogen and proteinous nitrogen than those from the southern Korea, but content of cellulose and lignin as well as the CN ratio of the former are inferior to those of the latter. Inami (1933) reported that the straws of the rice plants injured by coolness in northern Japan were larger in moisture content, total nitrogen and phosphate, and less in ash, reducing sugars, silica, cellulose and lignin in comparison with those of the non-injured plants. Kimora (1943), working with the same materials, noticed that the content of nitrogen as well as phosphoric acid was in inverse proportion to the ripeness, while that of the potash and silica was contrary to the above. Moreover, Miyake & Ishizuka (1937) concluded from the statistical studies on the relation of temperature to the ratio of fertilizer ingredient and the yield of rice grains in every district of Japan that the ratio of P_2O_5 and K_2O to N should be higher in the cooler regions than in the warmer, so far as the annual and accumulated temperature during the cultivation period is concerned. The results of these studies mentioned abovo are in accord with those of the author's experiments concerning the disease resistance of the rice plants grown uuder different temperature conditions. From these facts, it is concluded that the rice plants grown under cooler conditions are generally suitable for the nutriment of the blast fungus by the reason that their protoplasm is rich in nitrogen, and also liable to the invasion of the parasite because of the incompleteness of cell membrane due to the deficiency of silica and other membrane-constituting substances, such as cellolose, lignin, etc., while the plants grown under the warmer conditions become resistant on account of the physiological phenomena quite opposite to the above.

The rice blast disease is very prevalent every year in the temperate regions, especially in those of the northern latitudes, notwithstanding that the temperature during the rice cultivation in the above regions is lower than the optimum for the blast funguns. This fact is considered to be due to the decrease of resistance induced by the cool weather condition of these regions. Likewise, the rice plants raised in the subtemperate regions are susceptible during the vegetative period in consequence of coolness, but become resistant in the later stage on account of the warmer temperature.

On the other hand, in the subtropical rigions a marked difference is noticed in the mode of prevalence between the 1st- and 2nd crop. This difference is also considered to be chiefly due to the temperature conditions. For instance, in the case of the two regions, i. e. San-ah in Hainan and Taichung in Formosa, the difference of temperature during the vegetative period in the 1st- and the 2nd crop is about 5 and 10°C, respectively, since in the former place the temperature is 20 - 25°C in the 1st crop and 26-28°C in the 2nd, while in the latter it is 16 - 22° C and 27 - 28° C respectively. As has already been noticed by the author, the rice plants bccome very susceptible at 15-20°C, which are corresponding to the temperature during the seedling and tillering stage of the 1st crop in Taichung, moderately susceptible at 20 - 25°C, the temperature of the tillering period in the above-named, but is very resistant when they were grown at 27 - 29°C or more, which are the temperatures of the seedling- and tillering period in the 2nd crop of the same place. Moreover, it must be noticed in this connection that the temperature has an intimate relation to the disease escaping of the rice plants together with the length of day, since the length of each growth stage of the hosts is influenced by them, and moreover, the resistance of the plants is different according to their age (*vide.* chapt. v). For example, the length of each growth stage in the 1st- and 2nd crop at Taichung is as follows:

Table 50. Length of each growth stage of the variety "Taichu No. 65" at Taichung (24°09'N)

Crop	Sowing～ transplant-ing (Days)	Transpl.～ Maximum tiller. (Days)	Maximum tiller.～ bootlng (Days)	Booting～ heading (Days)	Heading～ maturaton (Days)	Total (Sowing～ maturation) (Davs)
1st	30	58	0	27	35	150
2nd	17	34	2	22	35	110

As shown in the above table, the length of each growth stage oi the 1st- and 2nd crop is very different from each other especially it is very remarkable in the case from the seedling to tillering stage, during which period the leaves are susceptible to the disease. It is also noticed that the 2nd crop passes through the critical period faster than the 1st crop. On the contrary in the tropical type the temperature condition is of minor importance as a controlling factor of prevalence, since in this region the temperature and the length of day are almost uniform throughout the year; consequently, their effect on the resistance of the plants is practically indistinguishable.

Section 2. Relation of Solar Rediation to the Resistance of the Rice Plants

As regards the effect of sunlight on infection, there are a considerable number of experiments, but most of the studies have been discontinued in a short time, and the experiments extending throughout the long period of plant growth have been very limited. Moshkov (1938)reported that Ribes becomes immune to *Cronartium ribicola* if the length of day is more than 17 hours but becomes susceptible in proportion to increase of day-length, and is most susceptible when it is shotened to 13 hours. On the other hand, however, according to the same author,the plants region resistance if it is shortened still more, becoming quite immune at the length of 9 hours and downwards. Rodenhiser *et al.* (1940) confirmed that when wheat plant were exposed to the three sorts of daily photoperiods, *i. e.* continuous, 10-11 h. daily and 8 h. daily they become more resistant to the bunt in the order named. Later they (1943) further confirmed that one variety "Canus which is resistant to all races of *Tilletia levis* and *T tritici* under the natural-day condition, became very susceptible when they were exposed to the continuous light. While the other, "Ulka was completely susceptible to all but one race under both day-lengths, and the resistance to this one was lowered by the long-day treatment. As regards the loose-smut of barley Leukel (1932) reported that the percentage of infection is some

what larger on the plants receiving a normal light period than on those exposed to the additional artificial illumination. Working with the rye smut, *Urocystis occulta*, Ling (1941) confirmed that the development of the fungus on the two varieties, Dakold and prolific, was similarly retarded by the short-day treatment and hastened by the long-day, but the final percentage of infection was increased in Dakold with the lengthening of the light period, whereas it was not significantly affected in Prolific. Recently Foster & Walker (1947) pointed out that tomato plants grown under the short-day or lower light intensity are predisposed to the *Fusarium* wilt to a greater degree than those conditioned under the long-day or higher light intensity. Johnson & Newton (1940) reported that, under the conditions from February to June in Winnipeg, the wheat plants at maturation are more susceptible when they are grown under the day length of 6 hours than when under that of 10 hours, though they are most resistant under the full day condition, and increase susceptibility if they were covered with a white cloth so as to reduce the intensity of light to 60 per cent of the full light condition. This result is not in accord with many of the experiments hitherto studied on the relation of sunlight to the cereal rusts, but it must be kept in mind that the former experiments were made on the adult plants, while all of the remainders were conducted with the use of the younger plants, accordingly, there may exist some differenec in reaction between them. It was also briefly recorded in the annual report (1929) of the Agricultural Experiment Station of the Department of Agriculture and Forestry of Japan that the blast disease occurs more severly under the short-day conditions than under the longer, though no details have been mentioned.

The author intended to study the effects of day-length, sunshine-duration and amount of insolation on the resistance of the rice plants, in order to confirm how these factors are important for conditioning the prevalency of the disease under consideration.

A. Relation of Daily Photoperiods to the Resistance of the Seedlings

All the potted plants to be exposed to light are daily removed to the open air from the dark, ventilated house (12x8x9(m.)) by means of a pushing truck on which they are placed during the course of the experiments and left there for given lengths of time. In the case of the exposure longer than the length of day-light the shortage in supplied by using artificial lights, *i. e.* a 100-watt tungsten lamp to every 5 pots at the height of 1 meter above the top of the plants. All the experiments were carried out at Taichung (24°09'N) at which the maximum and minimum length of day are 13.5 hours in June and 10.6 hours in December, respectively. The first experiment was undertaken at the tillering stage during the season of short day (11 hours) extending over 1 month.

Table 51. Results of the inoculation experiment with the plants treated with the different daily photo-periods during their tillering stage.

Daily Photo. period (h.)	Plant height (cm)	No. of tillers	No. of leaves	Length of Leaves (cm)	Width of Leaves(cm)	No. of Plant	Lesions per Leaf
6	64.0	1.3	5.2	41.9	0.79	1.68	0.32
8	63.4	1.6	5.2	37.9	0.76	2.48	0.48
10	68.2	1.6	4.9	33.9	0.88	2.65	0.54
12	65.9	2.3	8.4	40.9	0.95	6.88	0.82
14	64.1	2.8	9.5	41.3	0.82	5.62	0.59
24	52.4	2.6	8.7	32.2	0.76	2.55	0.29

Sown, Jan. 20, 1942. Treatment was started on Feb. 20. Inoculated, Mar. 20. The ratio of sunshine duration during this experiment was only 43 - 48%

As seen in the above table, susceptibility is increased in proportion to the length of day up to 12 hours, but sometimes decreased under the day length of 14 hours which are supplemented with 2-hour artificial illumination, and the highest resistance is noticed in the case of the whole day-illumination.

The second experiments were conducted during the season of the longest day length (13.5 hours) in order to confirm the effect of "long day" without use of artificial light, since the photosynthetic activity of plants is greatly impaired by the artificial illumination. In these experiments the

plants to be exposed were divided into two parts, viz. the one being exposed simultaneously at 6 o'cl.a.m. and removed to darkness after a given length of time, while the other being removed to the open air at different times in the mofning according to the schedule and equally exposed to the afternoon-light until sunset (7.30 p.m.). In other words, in the former the duration of exposure is similar in the morning and different in the afternoon, while in the latter it is quite opposite to the above.

Table 52. The results of the lst inoculation experiments with the seedlings grownunder different day lengths.

Daily photo-period(h.)	Height of plant (cm)	No.of tillers		Total length of leaves (cm	Width of leaves (cm)	No.of lesions per	
						Plant	Leaf
7	27.0	1.0	3.0	38.6	0.40	1.21	0.40
8	24.5	1.4	3.0	38.0	0.54	2.38	0.79
9	24.8	2.0	3.0	37.7	0.46	3.00	1.00
10	26.4	2.7	3.0	39.9	0.48	2.53	0.84
11	25.1	2.5	3.1	37.8	0.47	2.56	0.83
12	27.8	2.4	3.0	38.9	0.45	2.60	0.87
13.5	26.0	2.8	3.1	42.2	0.52	3.00	0.97

Treatment was started on June 4,1942. Inoculated on June 14.

The total sunshine duration during treatmnnt was 62.5 h.

Table 53. The results of the 2nd inoculation experiments with the seedlings grown under different day lengths.

Daily Photo-period(h.)	Height of plant (cm)	No.of tillers	No.of leaves	Total length of leaves(cm\	Width of leavns (cm)	No.of lesions per	
						Plant	Leaf
7	34.0	1.9	3.2	46.4	0.42	0.27	0.08
8	36.6	1.4	4.0	61.4	0.55	0.45	0.11
9	36.6	1.4	4.6	62.0	0.56	0.42	0.09
10	36.4	1.4	4.2	66.1	0.58	1.18	0.28
11	43.5	3.2	10.8	121.9	0.72	4.04	0.37
12	43.1	3.4	10.8	115.3	0.72	4.58	0.42
13	45.4	3.0	10.4	145.2	0.74	4.42	0.43

Treatment was started on July 5, 1942. Inoculated on July 19.

The total sunshine duration during treatment was 85.9 h.

The results of the experiment shown in table 52 is not so clear-cut. It is presumed that this might be partly due to the facts that the weather during the experiment was almost cloudy in the afternoon, and that the

photosynthetic activity is generally lowered in the afternoon as has already been noticed by Noguchi (1941). However that may be, in consideration of the data given in table 52 and 53, it is inferred that the rice seedlings may become resistant when they grow under the short day condition by the reason that they are feeble in growth and unsuitable for the nutriment of the parasite, but under the long day condition they become susceptible, though in the case of the extreme long day exposure they come to be highly resistant.

B. Relation of Sunshine Duration to the Rsistance of the Seedlings

This experiment was conducted particularly in the season when the ratio of sunshine duration attains to the maximum (67 - 69%) in order to minimize the probability of intercepting the direct sunlight. Considering the actual condition of sunshine in both crops, the experiment was arranged as follows:

(1) 24-hour exposure
(2) Whole daytime-exposure (from 7 a.m. to 6.5 p.m.)
(3) 9-hour exposure (from 7 a.m. to 4 p.m.), except the experiment of table 56, in which seedlings were exposed for 8.5 hours.
(4) Half day exposure (from 7 a.m. to 1 p.m.)
(5) Similar to the above, but for the remaining half daytime they are exposed to the diffused light (sheltered with marsh-reed screens).
(6) Exposed to the diffused light throughout the whole day

The condition mentioned in (5) is almost similar to that of the tillering stage in the lst crop (the first half of April) during which period the length of day is 12.5 h. with 5.5-hour sunshine duration, and as has already been stated, the disease is most prevalent. The plot (2), in which the day length and the sunshine duration were 11.5 h. and 67 - 68 percent, respectively, is almost in accord with the natural conditions of August, the tillering stage of the 2nd crop, since the day length and sunshine duration are 12.8 h. and 7.5 h., respectively. The results of the experiments are shown in tables 54 - 56, of which table l denotes the results of the experiments with the plants treated only before inoculation, while the remain-

ders are of those with the plants treated both before and after inoculation.

Table 54. The results of the lst inoculation experiments with the seedlings grown under the different conditions of sunshine duration in the open air.

Varieties employed	Treatment	Height of plants(cm)	No. of tillers	No of leaves	width of leaves (cm)	No. lesions per	
						Plant	leaf
Taichu No. 65	(1)	31.7	3.3	9.9	0.59	1.00	0.11
	(2)	52.9	4.6	16.9	0.75	10.48	0.62
	(3)	50.2	4.3	16.3	0.64	4.73	0.29
	(4)	27.8	1.0	3.6	0.25	0.18	0.05
	(5)	49.4	2.3	7.3	0.65	2.26	0.31
Zeng-tou uh-rwan-tzu	(1)	27.9	5.8	15.4	0.56	0.46	0.03
	(2)	55.9	8.7	29.9	0.74	1.19	0.04
	(3)	49.4	5.6	20.5	0.65	1.44	0.07
	(4)	23.8	1.0	3.1	0.24	0.20	0.07
	(5)	48.9	3.8	13 0	0.66	1.04	0.08

Treatment was started on Sept. 6, 1931. Inoculated on Sept. 16.

The totel sunshine duration was 77.3 h. in the control (plot 1).

Table 55. The results of the 2nd inoculation experiment with the seedlings grown uuder different conditions of sunshine duration in the glass house.

Varieties employed	Period of treatment	Treatment	Height of plants (cm)	No. of tillers	No. of leaves	width of leaves(cm)	No of lesions		Length of lesions (cm)
							Per plant	per leaf	
Taiohu No. 65	Before inoculation	(2)	36.3	1.3	3.8	0.41	4.89	1.29	0.49
		(3)	37.2	1.2	3.7	0.47	2.83	0.77	0.45
		(4)	33.7	1.2	3.6	0.44	0.50	0.14	0.41
		(5)	34.6	1.3	3.3	0.39	2.00	0.61	0.32
		(6)	26.1	1.0	2.6	0.35	0.21	0.08	0.20
	Before & after inoculation	(2)	36.1	1.2	3.9	0.47	5.15	1.32	0.47
		(3)	35.0	1.2	3.8	0.41	2.13	0.56	0.61
		(4)	30.6	1 2	3.4	0.39	1.34	0.39	0.55
		(5)	37.4	1.2	3.4	0.43	2.04	0.60	0.73
		(6)	26.1	1.1	2.6	0.29	0.60	0.23	0.38
Zeng-tou uh-rwan-tzu	Before inoculation	(2)	40.8	1.5	3.7	0.39	0.56	0.15	0.54
		(3)	44.4	1.3	3.8	0.52	0.30	0.08	0.40
		(4)	34.7	1.0	3.0	0.37	0.02	0.01	0.30
		(5)	41.7	1.1	3.4	0.45	0.02	0.01	0.40
		(6)	33.2	1.0	2.8	0.31	0.02	1.01	0.35
	Before & after inoculation	(2)	39.4	1.8	3.7	0.43	0.07	0.02	0.40
		(3)	41.4	1.7	3.7	0.48	0.05	0.01	0.30
		(4)	36.4	1·4	3.4	0.40	0.05	0.01	0.25
		(5)	41.1	1 5	3.8	0.47	0.02	0.01	0.34
		(6)	33.2	1.0	2.6	0.30	0.08	0.03	0.33

Treatment was started on Oct. 5. 1941. Inoculated. Oct. 13.

The total sunshine duration of the control(treated before inoculation) was 68. 5 h. and the same but treated before and after inoculation was 97. O h

Table 56. The results of the 3rd inoculation experiment with the seedlings grown under different conditions of sunshine duration in the glass house.

Varieties employed	Period of treatment	Treatment	Height of plants (cm)	No. of tillers	No. of leaves	Lenght of leaves (cm)	Width of leaves (cm)	No. of lesions	
								Per plant	Per leaf
Taichu No.65	Before inoculation	(1)	21.8	1.0	4.0	28.9	0.44	1.2	0.04
		(2)	32.2	1.7	4.1	45.3	0.53	10.3	0.23
		(3)	30.0	1.4	4.1	46.1	0.45	5 5	0.12
		(4)	28.0	1.0	4.1	42.2	0.36	4.6	0.10
		(5)	31.6	1 5	4.2	47.7	0.45	8.2	0.17
	Before & after inoculation	(1)	22.3	1.3	4.5	34.3	0.42	3.3	0.09
		(2)	33.1	1.3	4.9	53.7	0.53	14.6	0.27
		(3)	31.1	1.1	4.3	43.7	0.60	17.3	0.36
		(4)	53.1	1.0	4.1	30.8	0.39	4.2	0.41
		(5)	25,8	1.3	4.4	48.4	0.42	14.2	0.29
Zeng-tou-uh-rwan-tzu	Before inoculation	(1)	27.8	2.4	4.0	40.5	0.38	11.9	0.29
		(2)	40.8	3.0	4.3	69.6	0.50	10.4	0.15
		(3)	39.2	3.2	4.1	58.5	0.44	18.7	0.32
		(4)	31.1	1 2	4.2	59.9	0.38	0.9	0.02
		(5)	38.9	1.3	4.9	47.7	0 42	4.8	0.10
	Before & after inoculation	(1)	25.0	2.0	4.4	40.2	0.37	5.2	0.13
		(2)	40.7	3.2	4.2	68.1	0.51	9.5	0.12
		(3)	32.5	1.2	4.5	50.9	0.46	5.1	0.10
		(4)	30.2	1.3	4.2	60.1	0.40	2.1	0.03
		(5)	37.6	2.0	4.4	62.4	0.44	12.7	0.20

Treatment was started on Oct. 18. 1941. Inoculated. Oct. 29.

The total sunshine duration of the control(treated only before inoculation) was 85. 3 h. and the same but treated before and after inoculation was 116.6 h.

In all the experiments Taichu No.65 became most susceptible without exception by the whole daytime exposure (2), moderately susceptible by a half day exposure to the direct and diffused lights (5) or by 9-hour exposure (3), resistant by either a half day exposure (4) or by 24-hour exposure (1), and most resistant by the whole day exposure to the diffused light (6). The plants tend to become lighter in colour and feebler in luxuriance in proportion to decrease of light, while the plants exposed all day long are stoutest and rather ligher in colour, though feeble in luxuriance. From the facts mentioned above, it may be concluded that the rice plants become resistant by excess or insufficiency of light, though their thowgr is not normal, while under the light conditions favorable for the growth they beeome susceptible. In the experiments with "Zeng-tou-uh rwan-tzu", the same tendency was observed as in Taichu No.65, although the order of susceptibility of each plot was somewhat different from the latter. The disease development seems to be more rapid under the eon-

dition of slight insufficiency of light, since, as shown in table 56, the development of the disease in the plots which received the 8.5-hour-exposure or the half day-exposure to direct and diffused lights was superior to that in the full day exposure.

C. Relation of Amount of Insolation to the Resistance of the Seedlings

The plants were grown in the glass boxes of 1.5 x 0.6 x 0.6 (m) which were screened with papers different in their perviousness to light. Amount of insolation in every plot was determined by the intensity of illumination, as it is almost in parallel with insolation, and the amount of insolation in every plot could not be compared simultaneously owing to the lack of proper instruments. The value of intensity of illumination recorded in tables 57 and 58 was measured simultaneously under the certain conditions of cloudiness.

Table 57. Results of the lst inoculation experiment with the seedlings grown under different conditions of insolation.

Varieties employed	Treatmont		Intensity of illuminat. (lux)	Height of plants (cm)	No. of tillers	No. of leaves	leaf colour	No. of lesions	
	Screened with	For						per plant	per leaf
Taichu No. 65	Non-screened	Full day	5,000	25.6	1.6	3.6	++++	0.82	0.23
	Paraffined papers	Half day	4,000	34.5	1.6	3.9	+++	0.97	0.25
	Do.	Full day	4,000	36.6	1.3	3.2	+++	0.74	0.23
	White papers	Full day	2,000	35.9	1.0	3.0	++	0.67	0.22
	Thick brown papers	Half day	1,100	30.9	1.0	3.2	+++	0.29	0.09
	Do.	Full day	1,100	30.9	1.0	2.9	++	0.40	0.01
Zeng-tou-uh-rwan-tzu	Non-screened	Full day	5,000	30.8	1.9	3.1	++	1.74	0.59
	Paraffined papers	Half day	4,000	32.5	1.7	3.5	++	1.55	0.44
	Do.	Full day	4,000	32.5	1.4	3.1	++	0.10	0.35
	White papers	Full day	2,000	35.0	1.3	3.0	+	0.58	0.19
	Thick brown pepers	Half day	1,100	33.8	1.6	3.0	++	0.48	0.16
	Do.	Full day	1,100	30.5	1.0	2 6	+	0.53	0.20

Treatment was started on Nov. 23. 1941. Inoculated on Dec.2.

The total sunshine duration was 49.8 hours in the control(non-screened).

Table 58. Results of the 2nd inoculation experiment with the seedlings of Taichu No. 65 grown under different conditions of insolation.

Screened with	Intensity of illuminat (Lux)	Height (cm)	No. of tillers	No. of leaves	Total length of leaves (cm)	width of leaves (cm)	No, of lesions		Total N (%)
							Per plant	Per 1 cm of leaf 1	
Non-screened A	10,000	35.7	4.7	17.3	202.2	0.73	3.69	0.018	4.50
Non-screened B	7,500	47.1	2.2	8.3	114.2	0.43	1.19	0.010	4.62
Glass Plates	5,500	59.4	2.0	6.7	117.6	0.50	0.69	0.006	4.72
Paraffined pap.	3,000	48.9	1.0	5.0	59.8	0.47	0.79	0.013	4.28
White paper	2,500	48.7	1.0	4.7	79.6	0.30	0.27	0.003	4.34
Thick brown P.	1,600	47.9	1.0	4.7	69.5	0.40	0.25	0.004	4.40

Sown, Sept. 28, 1944 Treatment was started on Oct. 13. Inoculated, Oct. 24.
Nonscreened A - Kept in open air; Non-screened B - Kept inside glass-house.

The results of the above two experiments equally showed that the rice seedlings become resistant in proportion to decrease of insolation, though their luxuriance is in negative correlation with resistance. From the results hitherto stated, it is concluded that, so far as the sunlight conditions of the subtropical regions are concerned, the resistance is in inverse relation to the length of day, sunshine duration and intensity of light.

D. The Role of Sunlight as a Cause of Resistance of the Rice Plants and of Prevalence of the Blast Disease

Arakawa (1938) pointed out that the rice plants grown under the shaded condition are higher in nitrogen content, though the absolute value of the absorbed nitrogen is less than that of the non-shaded plants, but the content of silica is almost indistinguishable between the two. Sugahara (1942) also stated that the amount of nitrogen, potash and phosphorus is larger in the shaded plants than in the non-shaded, but calcium content is rather more abundant in the latter. In the authos's experiments, it was found that the content of total nitrogen was highest in the slightly-shaded plants and decreased with increase of interception, though it was not always proportional to the number of lesions appeared. According to the experiments of the above two authors the shaded plants are higher in nitrogen content and darker in leaf colour than the non-shaded, but it is

suggested that the shaded plants of these authors might be kept under the conditions corresponding to those of the slightly shaded plots of the present author. Furthermore, as shown in the following table, silicification of the epidermal cells of the leaves is positively correlative with the resistance.

Table 59. Number of the silicated epidermal cells of the leaves of the rice seedlings exposed to light for different length of time.

Varieties employed	Treatment	Number of silicated cells per unit area		
		Motor cells	Long & short cells	Stomatal cells
Taichu No. 65	24-hour exposure	2.50	1.92	0
	Whole daytime-hour exposure	0.20	0.02	0
	8.5-hour exposure	1.10	0.17	0
	Half day exposure	3.61	1.50	0
	Half-day exposure to direct and diffused lights	1.70	0·41	0
Zeng-tou-uh-rwan-tzu	24-hour exposure	2.00	0.08	0
	Whole daytime-hour exposure	0.00	0.00	0
	8.5-hour xposuree	0.08	0.02	0
	Half day exposure	0.30	0.00	0
	Half-day exposure to direct and diffused lights	0.00	0.00	0

From the results of the author's experiments already mentioned, the length of day is considered to be of rather minor importance as a cause of prevalence, although the susceptibility is very slightly increased in proportion to the length of daytime. As already mentioned in chepter 11, in the subtropics the sunshine duration of the 1st crop is about 2 hours shorter than that of the 2nd, and in the plots of the half day exposure to each of the direct- and diffused lights (corresponding to the 1st crop condition) the lesions are about half in the number of those in the plots of the whole day time-exposure (corresponding to the 2nd crop condition). It is difficult to interpret the natural phenomenon from the data of these inoculation experiments, since in nature the prevalence is severe in the 1st crop and very restricted in the 2nd. The same tendency is also noticed in the case of the solar radiation, since according to the author's experiments the rice seedlings are more resistant under the condition of lesser insolation than under that of the plentiful insolation, the former

corresponding to that of the 1st crop and the latter to the 2nd.

Section 3. Relation of Humidity to the Resistance of the Rice Plants

Tochinai & Komiya (1939) pointed out that the susceptibility of the rice seedlings to the present disease was almost unchangeable by treating them in the saturated humidity for 24 - 72 hours, but this experiment was concerned with the stimulative physiology extending over the short length of time. The author intended to confirm the effect of humidity on the resistance of the rice plants by treating them for a long time. The seedlings were cultured with Fukaki's solution (500 cc per glass bottle) inside the big bell jars (17 litre in capacity) for 10 days under the diffused light condition in the glass house, the desired humidity of the air inside the jars being approximately maintained by using sulphuric acid at a suitable concentration. After cultivation for the above-named period, the seedlings grown under different humidities were inoculated simultaneously by use of the ordinary method.

Table 60 Results of the inoculation experiment on the rice seedlings grown under different air humidities.

Air humidity(%)	Height of plants(cm)	No.of lesions per plant
97 - 100	31.5	2,57
94 - 99	34.2	2,80
84 - 95	36.0	3.30
75 - 88	30.5	2.22

Treatment was started on Apr.13, 1942. Inoculated, Apr,23.

The susceptibility and growth of the seedlings were greatly enhanced in the moderately humid conditions, such as 84 - 95 per cent of relative humidity, and they were impaired when the air was either extremely damp or dry. Nevertheless, as has already been stated in chapt.11, the relative humidity of paddy fields in any districts is not much different, so far as the comparison of the moisture conditions during the period of cultivation is concerned. From the reason already mentioned, air humidity may not be of major importance as a controlling factor of prevalence in nature.

CHAPTER V.
RELATION OF AGE OF RICE PLANTS TO BLAST RESISTANCE

As to the relation of age of cereals to the disease resistance, a considerable number of studies were reported, such as those of Stakman & Piemeisel (1917), Hursh (1922), Asmodt (1927), Harrington & Smith (1929), Johnston & Melchers (1929), Gassner (1916.1932), Kusano & Asuyama (1938), Das & Baruah (1947), etc. All those studies alike confirmed that in certain varieties or hybrid of wheat the adult plants are more resistant than the seedlings. Newton & Brown (1934) also pointed out that the immature tissues of certain varieties of wheat and rye are very susceptible to *Puccinia graminis* and are readily infected even by the biologic forms uncongenial to them, though the mature tissues are resistant to any forms. On the other hand, as regards the rice blast, studies are rather limited. According to Suzuki (1940), the blast fungus invades into the leaves of the seedlings of 25 days old, but is unable to attack those of three months old. On the seedlings bearing several leaves, Miyazaki (1930) proved that the upper (younger) leaves are more susceptible than the middle or lower (older), while Hemmi & Abe (1932) concluded that the middle leaves are most susceptible. The similar sort of experiments at Okayama Agr. Expt. Sta. (1932) showed the results quite opposite to that of Miyazaki. Ikata *et al.* (1931) reported that the necks of panicles are readily infected during the period from the beginning of heading to the culmination of it, and become resistant in the later stage of heading and thereafter. More recently, Andersen *et al.* (1947) roughly determined that the plants in the seedling and tillering stages are susceptible to leaf and sheath infection, and those from the later tillering to the late booting are very resistant to it, while the exposed parts of panicles are easily infected during the late booting and heading stages. Concerning this matter, more detailed studies were already undertaken by the present author (1943,e) and the results of them are

mentioned as follows;

The plants were cultured in pots in parallel with the 1st crop (Jan.-May) and the 2nd crop (July-Sept.), and inoculation was made on their leaves as well as on their necks of panicles at different intervals. In the present experiments the following two methods were used. In the first series of experiments plants were grown by sowing seeds simultaneously and inoculated in turn at regular intervals, i.e. 10 days for the 1st crop and 5 days for the 2nd (tables 61 and 63). In the second series of experiments, seeds were sown in turn at the regular intervals as mentioned above, and inoculation was made simultaneously when all the plants attained to the stages required (tables 62 and 64). In both of the series mentioned above, there are naturally some defects. For instance, in the former all the plants were not inoculated similarly, as the time of inoculation was different, and moreover, the environmental conditions during the incubation period were also different. On the other hand, in the latter they had been grown under the environmental conditions different from those of the normal periods of the both crops in proportion to delay of sowing.

A. The Change of Resistance of the Leaves Due to Ages

The results of the inoculation experiments made by the two methods are shown in the following four tables.

Table 61. Results of the 1st series of inoculation on the plants at different ages grown under the condition of the 1st crop.

Ages (Days old)	Sown on (Date)	Inoculated on (Date)	Plant growth at the time of inoculation					No. of lesions		Length of lesions (cm)
			Height (cm)	No. of tillers	No. of leaves	Total length of leaves (cm)	Width of leaves (cm)	Per plant	Per 1 cm² of leaf area	
10	1.20	1.30	3.9	1.0	2.0	3.4	0.19	0	0	—
20	"	2.09	8.1	1.0	2.2	10.7	0.26	0	0	—
30	"	2.19	23.3	1.1	4.3	25.6	0.40	0.33	0.032	0.35
40	"	3.01	35.8	2.0	10.8	80.5	0.50	4.43	0.110	0.40
50	"	3.11	42.0	2.4	15.0	195.4	0.68	15.20	0.114	0.40
60	"	3.21	50.5	3.2	20.8	238.4	0.70	21.00	0.126	0.35
70	"	3.31	58.0	4.5	28.0	350.7	0.97	4.23	0.012	0.23
80	"	4.10	65.0	4.9	25.0	368.0	0.98	4.40	0.012	0.15
90	"	4.20	70.0	5.4	29.0	488.4	1.05	0.41	Trace	0.15
100	"	4.30	63.0	5.0	26.0	439.0	1.10	0.02	Trace	0.15
110	"	5.10	66.0	4.6	20.0	320.0	1.10	0.10	Trace	0.10
120	"	5.20	70.0	4.0	18.0	280.0	1.10	Trace	Trace	0.10
130	"	5.30	70.0	4.0	16.0	240.0	1.10	0.05	Trace	0.10

Table 62. Results of the 2nd series of inoculation on the plants at different ages grown under the condition of the 1st crop.

Ages (Days old)	Sown on (Date)	Inoculated on (Date)	Plant growth at the time of inoculation					No.of lesions		Length of lesions (cm)
			Height (cm)	No. of tillers	No. of leaves	Total length of leaves (cm)	Width of leaves (cm)	Per plant	Per 1 cm² of leaf area	
10	5.20	5.30	9.0	1.0	2 0	12.9	0.29	0.18	0.070	0.30
20	5.10	"	20.0	1.3	4(6	40.2	0.49	1.00	0.051	0.38
30	4.30	"	33.8	2.3	7.2	78.3	0.59	3.24	0.070	0.45
40	4.20	"	48.4	7.4	21.6	369.6	0.82	31.13	0.102	0.45
50	4.10	"	57.6	7.8	26.8	490.0	1.00	16.17	0.033	0.36
60	3.31	"	59.3	7.8	27.6	520.0	1.00	13.00	0.025	0.30
70	3.21	"	65.4	7.8	29.0	642.5	1.15	0.38	0.001	0.20
80	3.11	"	70.4	8.8	34.0	753.9	1.15	0.20	Trace	0 20
90	3.01	"	68.6	8.8	32.0	777.4	1.10	0.45	0.001	0.15
100	2.19	"	65.9	7.8	30.0	563.1	1.10	0.50	0.001	0.12
110	2.09	"	65.0	6.7	27.5	480.7	1.10	0.10	Trace	0.08
120	1.30	"	66.1	5.6	20.5	451.8	1.10	0.05	Trace	0.08
130	1.20	"	65.6	4.5	21.0	346.6	1.00	Trace	Trace	-

Table 63. Results of the 1st series of inoculation on the plants at different ages grown under the condition of the 2nd crop.

Ages (Days old)	Sown on (Date)	Inoculated on (Date)	Plant growth at the time of inoculat.					No. of lesions	
			Height (cm)	No. of tillers	No. of leaves	Total length of leaves (cm)	Width of leaves (cm)	Per plant	Per 1 cm² of leaf area
5	7.06	7.11	3.5	1.0	2.0	3.4	0.20	0	0
10	"	7.16	9.0	1.0	2.5	17.6	0.30	0	0
15	"	7.21	18.5	1.1	4.5	36.6	0.35	0.76	0.060
20	"	7.26	24.2	1.8	6.2	87.0	0.35	1.74	0.057
25	"	7.31	31.0	2 5	12.2	155.4	0.72	6.22	0.057
30	"	8.05	48.4	3.7	14.9	218.9	0.82	14.20	0.080
35	"	8.10	57.1	5.0	18.0	438.0	0.90	10.95	0.029
40	"	8.15	65.1	7.0	27.0	731.5	1.10	2.19	0.003
50	"	8 25	68.0	7.5	30.0	741.9	1.10	Trace	Trace
60	"	9.04	69.0	6.5	34.0	747.5	1.00	Trace	Trace
70	"	9.14	71.5	5.6	30.2	757.5	1.00	0	0

Table 64. Results of the 2nd series of inoculation on the plants at different ages grown under the condition of the 2nd crop.

Ages (Days old)	Sown on (Date	Inoculated on (Date)	Plant growth at the time of inoculation					No. of lesions	
			Height (cm)	No. of tillers	No. of leaves	Total length of leaves (cm)	Width of leaves (cm)	Per plant	Per 1 cm^2 of leaf area
5	9.09	9.14	4.9	1.0	2.0	3.8	0.20	0	0
10	9.04	"	10.8	1.0	2.0	11.6	0.30	0.15	0.043
15	8.31	"	19.5	1.1	3.5	30.9	0.36	0.34	0.031
20	8.25	"	27.6	1.3	4.2	39 2	0.40	2.38	0.152
25	8.20	"	33.2	1.8	6.8	75.8	0.57	5.40	0.125
30	8.15	"	44.0	3 0	15.5	259.7	0.75	10.52	0.054
35	8.10	"	46.4	3.5	16.5	301.8	0.78	17.78	0.076
40	8.05	"	56.1	6.5	25.0	450.4	0.81	2.50	0.001
50	7.26	"	61 8	6.8	32.5	804.5	1.00	0.30	Trace
60	7.16	"	70.0	6.2	26.0	905.0	1.10	Trace	Trace
70	7.06	"	70.8	5.5	24.0	700.8	1.10	Trace	Trace

As will be clear from tables 61 - 64, the leaves are susceptible during the seedling and tillering stages except for the very young stage in which the leaves are free from the disease, and become resistant at the last stage of tillering, somewhat increasing during the stage from heading to maturity with the lapse of time. Duration of susceptibility and resistance is dependent upon the environmental conditions, particularly on temperature. For instance, the plants under the condition of the 1st crop (tab.61) became susceptible 30 days after sowing, and maintained susceptibility for 50 days, especially most susceptible during the period from the 50th to the 60th day after sowing, but those under the condition of the 2nd crop (tab. 63) reached to the above stage within 15 days after sowing and remained susceptible for 25 days, being most susceptible during the period from the 25th to 30th day after sowing. Moreover, the younger seedlings shown in table 62 passed the susceptible stage faster and became resistant earlier than those in table 61. This difference may be explained by the reason that in the former experiment the temperature was somewhat higher than in the latter. More details as regards the matter will be shown in fig.16 which was photographed from the materials obtained from the experiment shown in table 62. The above-mentioned phenomena were also confirmed by the field experiments

performed during spring and autumn, the most suitable seasons for the prevalence of the disease.

Table 65. The transition of the blast infection of the leaves of the rice plants at different ages grown under the field conditions of autumn in 1942.

Date of observation	Days after sowing	Grown stage	Height (cm)	No. of tillers	Width of leaves (cm)	No. of lesions	Length of lesions (cm)
10.25	10	Seedling	6.0	1.0	0.2	0	—
11.05	21	Do	15.1	1.0	0.3	0	—
11.15	31	Early stage of tiller.	21.4	2.8	0.5	0	—
11.25	41	Do.	24.3	8.8	0.6	8.0	0.9
12.05	51	Tillering	25.4	13.0	0.6	14.0	0.9
12.15	61	Do.	26.8	17.0	0.7	7.0	1.3
12.25	71	Do.	30.2	22.8	0.8	6.4	1.8
1.05	82	Do.	36.9	24.1	0.8	6.2	1.9
1.15	92	Do.	41.4	26.1	0.9	8.2	1.7
1.25	102	Maximum tillering	41.6	25.9	0.9	9.4	0.6
2.05	113	Do.	42.9	22.5	0.9	2.0	0.4
2.15	123	Do.	43.7	20.1	0.9	0	—
2.25	133	Do.	43.9	21.0	0.9	0	—
3.05	141	Booting	44.2	20.0	1.0	0	—
3.15	151	Do.	51.0	21.0	1.0	0	—
3.25	161	Do.	62.1	22.1	1.1	0	—
4.05	172	Heading	64.1	20.0	1.2	0	—

All the plants were sown on Oct. 15 and transplanted on Nov. 5, 1942.

Table 66. The transition of the blast infection of the leaves of the rice plants at different ages grown under the field conditions of spring in 1943.

Date of observation	Days after sowing	Growth stage	Height (cm)	No. of tillers	Width of leaves (cm)	No. of lesions	Length of lesions (cm)
3.25	10	Seedling	5.8	1.0	0.2	0	—
4.05	21	Do.	14.0	1.0	0.4	0	—
4.15	31	Do.	24.9	9.0	0.6	0.5	0.3
4.25	41	Early stage of tillering	31.2	15.0	0.8	1.3	0.8
5.05	51	Tillering	35.0	18.0	0.8	11.6	1.8
5.15	61	Do.	38.4	18.5	1.1	67.8	3.0
5.25	71	Maximum tillering	54.0	18.9	1.1	30.4	1.9
6.05	82	Booting	67.6	13.5	1.1	5.8	0.7
6.15	92	Heading	78.6	13.8	1.1	0.2	0.4
6.25	102	Do.	93.2	13.5	1.1	0	—
7.05	112	Maturity	100.1	13.4	1.2	0	—
7.15	122	Do.	101.4	12.8	1.2	0	—

All the plants were sown on Mar.15, and transplanted on Apr.14, 1943.

B. The Change of Resistance of the Necks of Panicles due to Ages.

It was shown by the following inoculation experiments that the necks of panicles are highly susceptible when they are still enclosed with the sheaths, but become resistance proportionately with the lapse of time after heading.

Table 67. Percentage of infection resulted from the inoculation on the necks of panicles at different grades of maturity.

Days after heading	Experiment 1	Experiment 2	Experiment 3
− 3 ※		38.0	68.0
− 2 ※	55.6	59.0	45.0
− 1 ※	56.4	36.0	72.0
0 ※※	25.8	40.0	38.5
1	11.5	34.0	19.4
2	7.8	15.0	13.2
3	8.5	40.0	25.1
4	14.1	18.0	8.0
5	12.9	22.0	15.3
6	12.5	10.0	7.4
7	11.9	8.0	14.0
8	11.1	18.0	14.8
9	11.9	22.1	15.4
10	16.4	10.8	4.0
11	10.8	5.0	9.0
12	15·8	8.0	0
13	7.8	2.0	10.3
14	9.0	0	3.5
15	5.0	0	0
16	0	7.0	4.0

Expt. 1 - Inoculation, May 24, 1943; Observation, June. 8.

Expt. 2 - Inoculation, Aug. 9, 1943; Observation, Aug.24.

Expt. 3 - Inoculation, Aug. 20, 1943; Observation, Sept. 5.

※ Inoculation, was made on the very young necks made bare by unfolding the sheath. The sign (-) means the days before the time of heading.

※※ Inoculation was made at the time of heading.

C. Mechanism of Resistance Induced by Age-difference

As early as 1924, Hursh pointed out that the stems of wheat plants increase the resistance to *Puccinia graminis* with ages on account of an

extensive development of sclerenchyma which is impenetrable to the invading hyphae. This theory was also supported by Hart (1931). On the other hand, Newton & Brown (1934) reported that stem rust resistance of the immature and mature tissues of wheat is not due to the morphological characters but is rather due to the cytological and protoplasmical nature. Working with the rice blast disease, Suzuki (1937, 1940), confirmed that the thickness and silicification of the epidermal cell walls of 3-month adult plants developed more extensively than those of the 25-day seedlings which were easily invaded by the fungus while the former was apparently free from invasion.

(a) The microchemical change of the epidermal cells

The results of the exepriments will be summarized as follows:

(1) Cutin was barely positive at the outer walls of the motor cells, especially at those of the center, but no difference of reaction was recognized at any ages studied.

(2) Fection was demonstrated most clearly at the motor cells, and slightly at the stomata, but almost unrecognizable at the remaining cells. The reaction of this substance tends to become slightly weakened in proportion to the age.

(3) The reaction of cellulose was almost similar to the above.

(4) Lignin was hardly recognizable in the epidermal cells of the younger seedlings, but after the later stage of tillering this was definitely demonstrated.

(5) Silica was increased in proportion to the ages, as will be shown clearly in table 68.

In view of the data mentiond above, it is inferred that the outer walls of the pepidermal cells of the rice plants may serve as a barrier to the invasion of the blast fungus in proportion to the increase of their ages, since the thickening, lignification and silicification of them keep up with the age.

Table 68. Number of the silicated epidermal cells per unit area at the middle part of the top leaves of the rice plants at different ages.

Days atfer sowing	Motor cells	Long cells	Short cells	Stomata
10	1.05	0	0	0
20	2.85	0.75	0.06	0
30	2.40	2.00	0.72	0.49
40	2.80	1.04	0.60	1.36
50	3.04	2.80	0.51	0.40
60	4.45	2.40	2.18	1.06
70	10.09	4.03	4.71	5.00
80	9.90	2.60	1.35	6.14
90	5.30	4.71	1.00	7.01
100	7.66	7.00	1.67	6.17
110	7.00	4.08	2.33	3.00
120	9.22	5.25	2.02	1.80
130	8.64	4.35	3.10	0.54

The samples of this experiment are similar to those shown in table 62.

(b) The anatomical change of the internal tissues of the leaves at different ages

As seen in tables 61 - 64, some minute spots appear on the leaves at the resistant stage, but they never develop to the normal lesions on account of inability of the mycelium to spread in a lateral direction. The transverse sections of the leaf tissues of the plants employed in the experiment of table 62 were observed under microscope for comparing the pa tho-histological change of the internal tissues after soaking them in phenol. The lesions at the susceptible stage (Fig. 16. A - E & fig. 19. A).

The typical lesions produced on the seedlings at the age of 40-50 days old consist of the following three zones, viz. the venenate (outer), necrotic (middle), and disintegrated (center) zones.※ With phenol these zones stain yellowish brown, blackish brown and greyish brown, respectively, though the healthy tissue is transparent. The disintegrated area is dry and shriveled, bearing the conidiophores of the fungus, while the other two zones almost keep the original form of the tissues. The lateral spread of these areas is hindered by the large vascular bundles and the sclerenchymas (stereom) above and below the former, but the smaller bundles are of no use for preventing the development of the parasite.

The small lesions at the moderately resistant stage (Fig. 16, F, & fig. 19,B).

On the 60 days old seedlings, the lesions are small owing to the

※ Termed following Yoshii (1937).

feeble development of the disintegrated zone and bear a little number of conidiophores. The vascular bundles and sclerenchymas become barriers to prevent the enlargement of each zone. Moreover, some minute lesions which are usually produced on the resistant leaves mentioned below are also recognized.

The minute lesions at the resistant stage (Fig. 16, G, & fig. 19,C - D).

On the adult plants older than 70 days, the lesions are minute, dot-like and blackish brown simulating those of Helminthosporium disease, as the dark colour of the necrotic zone predominates over the disintegrated zone. The disintegrated zone bears no conidiophore and the isolation of the pathogenic organism from this zone is almost unsuccessful. Moreover, in some cases this zone is absent. The lesions on the plants older than 100 days are much smaller in size and lighter in colour, since the necrotic zone is less prominent and often indistinguishable from the venenate zone (fig.19, D). The enlargement of the lesions is completely hindered by the small vascular bundles and the sclerenchymas above and below or around (selerenchyma sheath) the former. This fact seems to be in harmony with the result of the study of Kawamura (1940) which revealed that on Oryza minuta, the resistant species, the blast fungus produced the lesions which were often made of a small number of necrotic cells without normal venenate tissues.

As has been mentioned above, Hursh (1924) pointed out that the ratio of sclerenchyma to collenchyma has an important bearing upon the stem rust resistance of wheat plants. Hart (1931) also stated that the extent of sclerenchymatous bands and the distance between them have an intimate relation to the development of the sorus of stem rust. Concerning the rice blast disease, Nagai & Imamura (1930) memtioned that the necks of panicles of the plants grown under nitrogen deficiency are more resistant than those under excess of nitrogen because of the presence of a small amount of collenchyma and the more extensive development of sclerenchyma. Suzuki (1933) noticed that the sclerenchymas of the leaves of rice plants grown in the moist soil or in the flooded soil are

formed more extensively than those in the dry soil, the latter being more susceptible than the former. This finding was also confirmed by Hemmi *et al.* (1941) who worked with the leaves and necks of panicles of different varieties as well as with those grown under different environmental conditions. However, these results are not in agreement with those of the experiments made by Ikata *et al.* (1931). Ito & Shimada (1937), etc. Judging from the author's measurement, the number of the vascular bundles per one leaf and the distance between them have almost no relation to resistance, since the width of collenchyma becomes wider in proportion to the enlargement of size of the leaves, although the former also incresses in parallel with age, as seen in the following table.

Table. 69. Number of the vascular bundles per one leaf and the mutual distance from each other in the rice plants at different ages.

Days old	Grade of resistance	Width of leaves(cm)	Large vascular bundles		Small vasculer bundles	
			Number	Distance(μ)※	Number	Distance(μ)
20	Suscept.	0.54	5	720	24	153
70	Resist.	0.95	7	1,290	46	173
90	Resist.	1.15	9	1,440	46	177

※ Distance between each sclerenchyma above the vascular bundle.

As has already been stated, in the adult plants the enlargement of lesions is prevented by the small vascular bundles, but in the seedlings even the large vascular bundles or the midribs can hardly arrest the development of the disease. It is clear from this fact that the prevention of the lateral spread of lesions is correlated with the degree of development of the vascular bundles and not with their quantity nor the distance between them. The sclerenchymas associated with the midrib are largest and those with the small vascular bundles are smallest, though in general those below the vascular bundles (above the lower epidermis) are usually largar than those above them (below the upper epidermis). The size and number of the sclerenchymatous cells as well as the thickness of the cell walls those above the vascular bundles increase in proportion to the age of plants, as seen in table 70 and fig. 19, E - L.

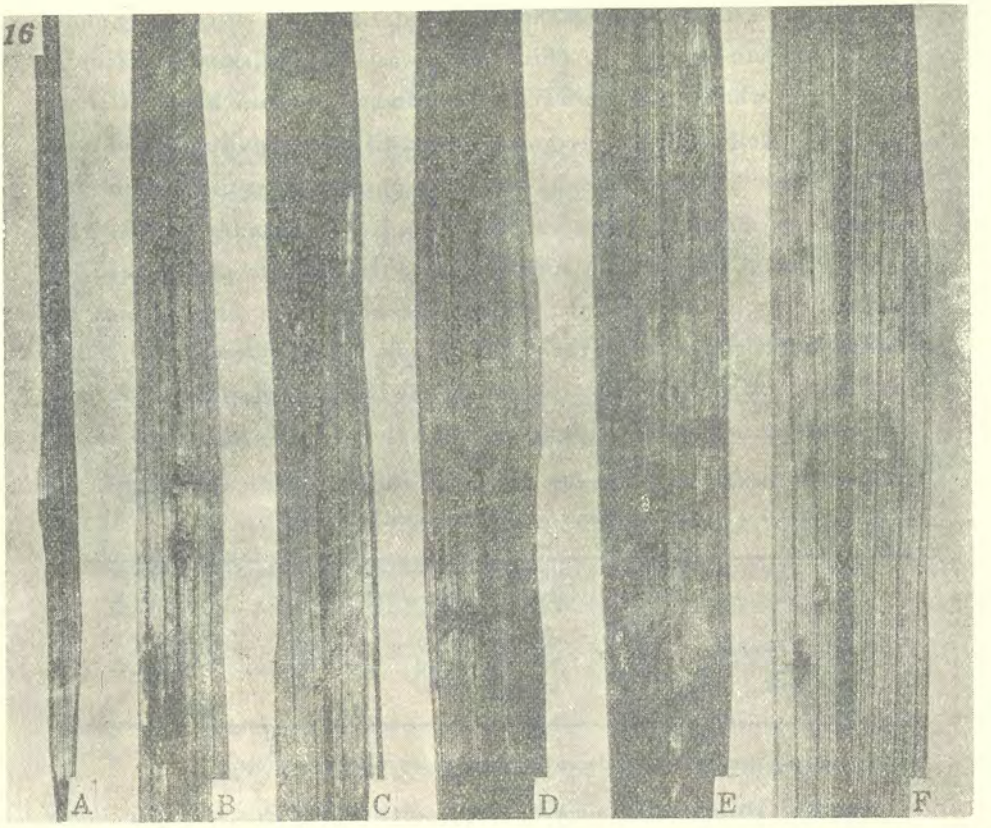


Fig. 16. The lesions on the leaves at the different ages (The samples are similar to those of table 62).

A . 10-day. B . 20-day, C . 30-day, D . 40-day, E . 50-day, F . 60-day.

Fig. 17. The blast injury of the rice plants at different ages grown under the field condition
A - The early stage of tillering; B - The later stage of tillering; C - The booting stage.

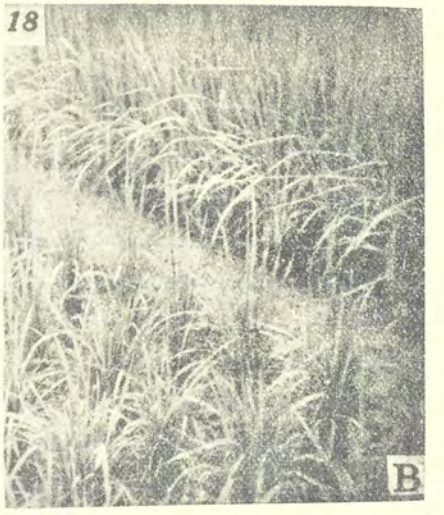


Fig. 18. The blast injury of the rice plants at the different ages in the paddy field.
The lower half - The tillering stage; The upper half - The early stage of booting.

Table 70. Results of measurement on the sclerenchymas above the vascular bundles of the leaves at different ages.

Days old	Grade of resistance	Thickness of leaves (μ)※	Midribs		Large vas. b.		Small vas. b.		Thickness of cell walls(μ)※※
			Width x thickness (μ)	No. of cells	Width x thickness (μ)	No. of cells	Wibth x thickness (μ)	No. of cells	
10	Suscept.	81	39x15	11	33x15	10	15x 8	2	1.0
30	Suscept.	90	63x21	25	45x21	17	21x12	5	2.7
50	Mod.sus.	95	81x25	34	48x21	19	22x12	6	2.7
70	Resist.	99	81x27	37	66x24	21	30x15	7	2.9
90	Resist.	105	93x28	49	78x27	38	30x18	9	3.1

※ Measurement at the small vascular bundles.

※※ Measurement on the cells constituting the sclerenchymas above the small vascular bundles.

In addition, Moules reaction was applied to confirm the distribution of lignin at the different tissues of leaves of different ages.

Talbe 71. Lignification of the different tissues of the leaves of different ages.

Days old	Grade of resist.	Epidermal cell wall	Midribs		Large vas. b.		Small vas. b.	
			Scler.※	Sheath※※	Scler.	Sheath	Scler.	Sheath
10	Suscept.	—	—	—	—	—	—	—
20	Suscept.	—	±	±	—	—	—	—
30	Suscept.	—	+	+	+	+	—	—
40	Suscept.	—	+	++	+	++	±	+
50	Mod. sus.	—	++	++	++	++	+	+
60	Mod. resist.	—	++	++	++	++	+	++
70	Resist.	±	+++	++	+++	++	++	++
80	Resist.	+	+++	++	+++	++	+++	++
90	Resist.	+	+++	++	+++	++	+++	++

※ The sclerenchymas above the vascular bundle.

※※ The sheaths of the vascular bundles (the sclerenchyma around the bundles).

These facts further confirm the results of the previous studies on the pathological anatomy which revealed that the enlargement of lesions is hardly checked even by the larger vascular bundles at the susceptible stage, but is easily arrested at the slightly susceptible stage, in the latter case the small vascular bundles may serve as a barrier to prevent the disease develompent.

(c) Content of nitrogen and carbohydrate in the leaves at different ages

The lesions of the blast disease usually assume a fusiform shape,

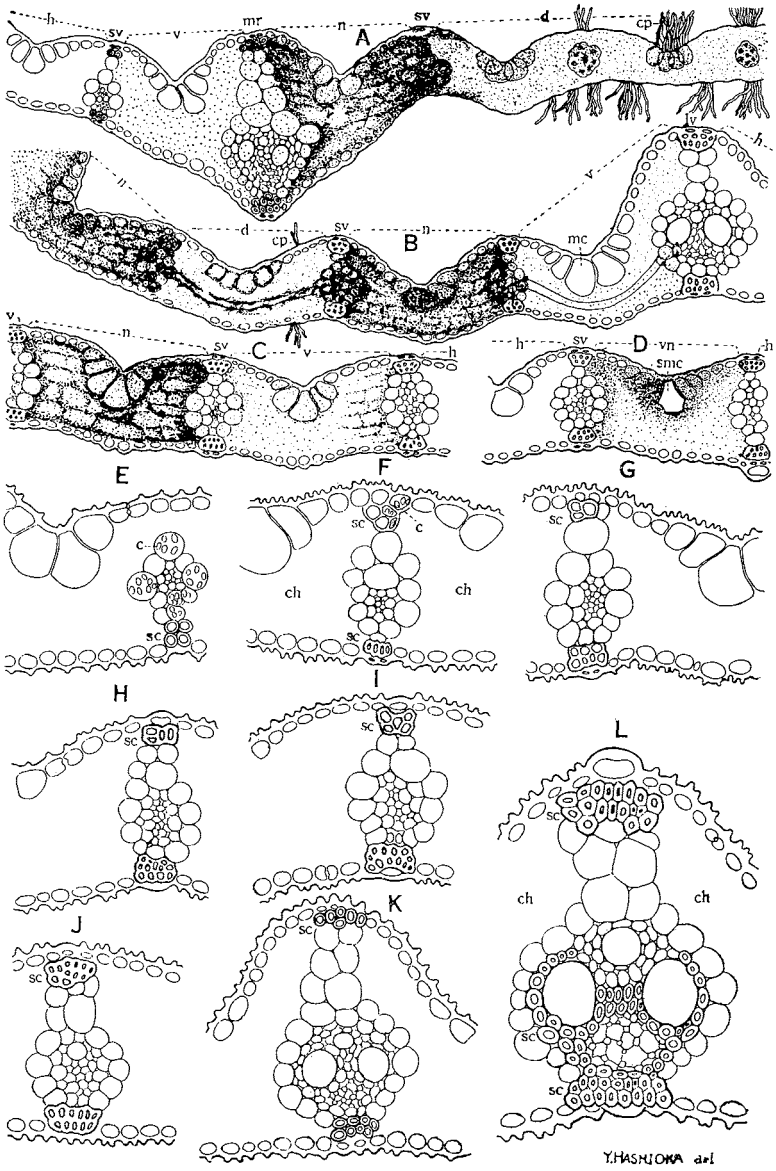


Fig.19. Pathological anatomy of the leaf tissues and the vascular bundles of them of rice plants at the different ages.

A - D. The transverse sections of the lesions (Winkel 5x3a, camela lucida drawing): A . 20-day, B . 60-day, C . 90-day, D . 110-day,

E - J. The small vascular bundles (Do., 5 x 5a): E . 50-day, F . 10-day, G . 20-day, H . 50-day, I . 70-day, J . 90-day.

K - L. The large vascular bundles (Do.): K . 10-day, L . 90-day

Abbreviations

h - Healthy area,	lv - Large vascular bundle,
v - Venenate zone,	sv - Small vascular bundle,
n - Necrotic zone,	sc - Sclerenchyma,
d - Disorganized zone,	ch - Chlorenchyma,
cp - Conidiophore	c - Chloroplast,
mr - Midrib,	smc - Silicated motor cell.

since the longitudinal development of the lesion can be made by way of the collenchyma, but the lateral extension is checked by the sclerenchyma in the vascular bundles. In the resistant stage, however, even the longi tudinal development is also prevented to a great extent. This fact seems to suggest that the chlorenchymatous tissues may also serve as a barrier at the advanced stage of plant growth. The author made some comparative studies on the amount of nitrogen and carbohydrate present in the leaves and sheaths of the rice plants at different ages in order to clarify whether or not they bear any relation to the resistance of the plants at different ages, since the blast fungus grows well when supplied with sufficient nitrogen (Abe. 1938), and the carbon-nitrogen ratio of the rice plants is in parallel relation to resistance when they are grown under different temperature conditions (*vide.* chapt.IV).

Table 72. Content of nitrogen and carbohydrate in the leaves of the rice plants at different ages.

Days old	Resistance	Nitrogen (%)	Carbohydrate(%)	CN ratio
10	Susceptible	3.83	14.02	3.66
20	Susceptible	3.88	22.18	5.72
30	Susceptible	3.79	23.21	6.12
40	Susceptible	3.11	25.11	8.07
50	Moder. suscept.	2.62	30.89	11.79
60	Moder. resistant	2.71	32.67	12.05
70	Resistant	1.89	34.82	18.42
80	Resistant	1.53	45.05	29.44
90	Resistant	1.89	42.78	22.63
100	Resistant	1.53	45.78	29.92
110	Resistant	1.71	46.17	27.00
120	Resistant	1.64	50.59	30.85
130	Resistant	1.26	42.78	33.95

Johnson *et al.* (1935) pointed out that the nitrogen content is lower in the mature parts of wheat which are resistant to the stem rust than the immature. According to Iso *et al.* (1934), Inami (1937), Kasugai (1939), Matsuki *et al.* (1942), Enomoto (1941). etc., the nitrogen content in the leaves of the rice plants decreases with the lapse of time, while carbon-nitrogen ratio increases in proportion to ages. The author's analysis not only confirmed the results of the above workers', but also

clarified that nitrogen content would play an important factor of susceptibility, since the decrease of it was especially remarkable in the 70-day seedlings, on which leaves the number as well as size of the lesions apparently decreased (*vide*. table 62).

(d) Morphological change of leaves and stems

As already stated, the very young seedlings whithin 20 days old in the lst crop or those within 10 days old in the 2nd crop are all free from the disease under the experimental and field conditions notwithstanding the fact that they are susceptible, so far as their anatomical and chemical conditions are concerned. This seems to be due to inability of invasion of the fungus into host tissues because of the difficulty of keeping dew drops on the leaves. The very young seedlings at the seed-beds bear the water drops due to guttation on the water pores situated at the margin of the leaves or at the top of them and keep only a very little number of dew drops at the junction of the leaf blades and the stems. This was also confirmed in the following inoculation experiments. The seedlings were sprayed with spore-suspension in water, a special care being taken to disperse the liquid in fine particles on the leaves, but the particles gathered together due to surface tension and dripped from the leaves, or they evaporated shortly after that, if they were dispersed distantly by using a very little amount of the water, and prevented to fall in large drops. For these reasons the dew drops may not be able to remain longer on the leaves. This seems to be due to the fact that the very young leaves grow rather straight in narrower angles with the stems than the older ones, or to the fact that the width of the former is too small to keep the dew drops on them, even if they are artificially placed horizontally.

From the facts mentioned above, it is concluded that the positive correlation between the blast resistance of the leaves and the age of the host seems to be due to the anatomical change of the walls of the epidermal cells and the sclerenchymas in the vascular bundles and also to the change of the chemical composition of the leaf tissues, particulary carbon-nitrogen rotio.

This fact is important as a controlling factor of prevalence int he

regions where the period which is favorable for growth of the fungus under consideration is longer than that of the prevalent season. In the northern limit of the rice crop, the prevalence is restricted only within the mid-summer during which season the disease of ears is prevalent, since the favourable temperature condition and the host susceptibility fall in with each other, and no prevalence is noticed during the seasons other than the above-nomed by the reason that the weather is too cool for the growth of the parasite, even if the host plants are susceptible. While the regions south of the above, including southern temperate, sub-temperate, subtropical and tropical regions, the prevalence is restricted to a rather short period notwithstanding that the temperature is favourable for the parasite all the year round or at least during several months, since the susceptible stage of the host plants does not last so long. Namely, in the temperate, subtemperate and the subtropical regions, where the temperature conditions vary at different seasons, the prevalence is determined by the temperature factor in combination with the host susceptibility relation, but in the tropical region where the temperature condition is almost uniform throughout the year, this is controlled merely by the above-named resistance-susceptibility relation of the host. Especially in the subtropical regions, the prevalence is chiefly restricted only to the period of tillering of the lst crop due to the phenomenon resulted from the host-parasite complex with regard to temperature, as will be mentioned in detail in chapt. VIII.

CHAPTER VI.

THE INHERENT RESISTANCE OF THE TROPICAL VARIETIES

Section 1. Varietal Resistance of the Rice Plants Endemic to the Different Latitudinal Regions

Sawada *et al.* (1927) pointed out from their field observations in Formosa that in most cases the infection of the neck of ears is severer in the Formosan varieties than in the Japanese ones. While, under Korean conditions, Nagai & Imamura (1930) observed that the neck of certain varieties endemic to Formosa is more resistant than those to Japan and Korea. As to the varietal resistance of the leaves, it was noted by the staffs of Ponape Branch Station of Research Institute of Tropical Industry (Nanyo-Cho, 1929, *et passim*) that under the field conditions the varieties native to Japan are very susceptible in comparison with those endemic to tropical Asia. Nagai (1926) confirmed by means of field inoculation in the seed-beds that the average percentage of the survived seedlings in the plots of 353 Japanese varieties was only 8.6 per cent, while in the plots of 32 varieties endemic to Formosa, South China and Java it was as high as 50.3 per cent. Nagai & Suzuki (1932) further confirmed the similar phenomenon in Korea. Comparing with the varieties native to Japan and tropics, Nakatomi (1926) also recognized the similar fact. In the recent years, the present author (1943,*b*;1944,*b*) confirmed by means of inoculation that the leaves of the Japanese varieties are more susceptible than those of the Formosan as well as Hainan varieties. Tasugi (1943) also made an inoculation experiment with several varieties of Japan, tropical Asia and America, and came to the conclusion that certain varieties native

to the last two named are more resistant than those of the first.

The author intended to confirm whether the varietal resistance is related to the geographical distribution of the varieties concerned or the varietal resistance of the leaves is correlated with that of the neck of ears as well as node of culms, since the exact knowledge on these relations is necessary for the breeding of the resistant varieties. For this purpose, the resistance of the numerous varieties amounting to almost four hundred which are native to the different latitudinal regions in Asia has been compared by means of the artificial inoculation in the glass house as well as by considering the data obtained from the natural infection in the field, since all the foregoing studies stated above had been carried out not only with the use of a limited number of varieties or those endemic to rather limited localities, but also with no consideration on the neck of ears emerged under different environmental conditions.

A. Varietal Resistance of the Leaves

As to this matter, many inoculation experiments as well as field observations have been made by the author in the past five years, but in this place only the following five experiments will be described. The symbols (capital and small letters) marked in the series of the experiments mentioned below coincide with those shown in each column of table 74.

(i) Inoculation of the potted seedlings grown under the glass-house conditions

(A) Inoculation of the 40-day seedlings grown under the flooded conditions in the pots (sowing, Jan.10,1945; inoculation, Feb.19). Varietal resistance was compared by counting the number of lesions per seedling(a), by measuring the length of lesions(b), and by presuming the grade of sporulation(c).

(B) Inoculation of the 40-day seedlings grown under the upland condition in the pots (Sowing, Aug.21,1946; inoculation, Sept.30). The observation was made 10 days after inoculation(Oct.10) by determining the infection type shown in table 73 and fig.20.

Table 73. Infection types of the seedling-leaves of the different varieties endemic to the different latitudinal regions.

Type	Shape of lesions	Colour of lesions	Sporulation	Grade	Number of lesions	Plant vigour	Representative varieties (Habitat)
A	large, typical fusiform	Dark grey	Abundant	3	Numerous	Withered	Benkei (Japan)
				2	Moderate	Enfeebled	Taichu No.150 (Formosa. "Horai")
				1	Meagre	Normal	Nakabo (Formosa, mount.)
B	large fusiform or allied shapes	Brown	Moderate to Slight	3	Numerous	Enfeebled	P.T B.10 (India)
				2	Moderate	Enfeebled	Mino-mochi No.1 (Japan,upland)
				1	Meagre	Normal	Tjina (Lesser Sunda)
C	Small lesions of various shapes	Brown	Slight to none	3	Numerous	Somewhat enfeebled	Gaisen (Japan, upland)
				2	Moderate	Normal	Hu-tzu (Formosa, lowland)
				1	Meagre	Normal	I-kung-pao (Formosa, lowland)
D	Minute dot-like lesions	Brown to blackish brown	None	3	Numerous	Almost normal	R.T.S 27 (Fr.Indo-China)
				2	Moderate	Normal	Macan Sapok (Philippine)
				1	Meagre	Normal	Kokko-mochi (Japan, upland)
E					No lesion		Padi Atjeh (Celebes)

(ii) Inoculation of the potted plants grown in the open air (a wiregauze house)

(C) Inoculation of the plants at the tillering stage (45-day plants) grown under the flooded condition (sowing, Aug.30,1946;inoculaion, Oct.14). The results were recorded in the same manner as shown in (B).

(D) Inoculation on the 30-day seedlings grown under the upland condition (sowing, Sept.14, 1946 ; inoculation, Oct.14). The results were recorded by the same manner as (B).

(iii) The natural infection on the plants at the tillering stage in the paddy field.

(E) Natural infection in the lst crop (Sowing, Jan.20,1945; observation, May 5) was compared by counting the number of lesions per seedling(a), by measuring the length and width of lesions(b), and by deciding the grade of sporulation(c).

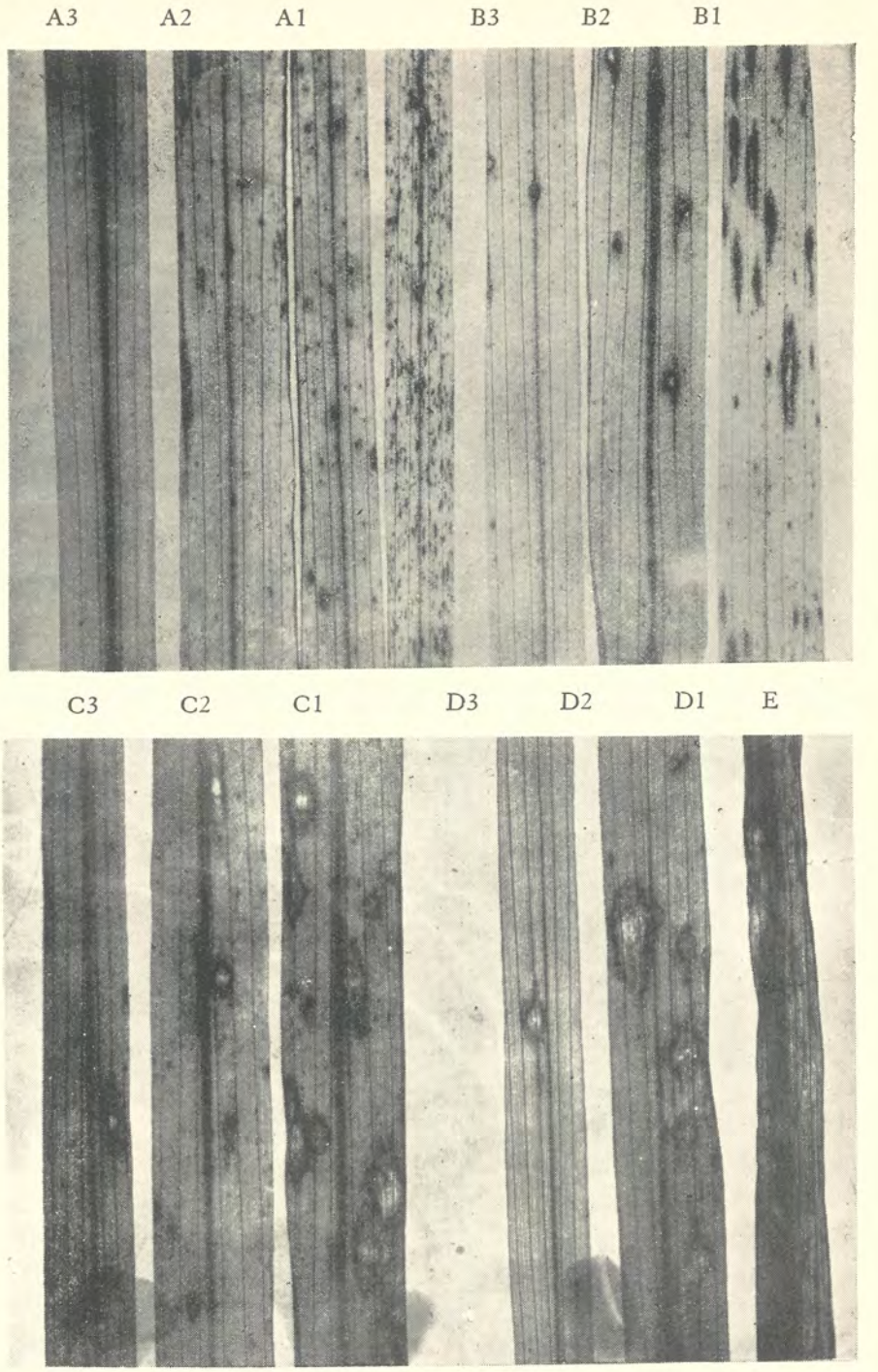


Fig.20. Infection types of the seedling-leaves of the different varieties.

A3 - Benkei (Japan)
A2 - Taichu No.150 (Formosa, 'Horai')
A1 - Nakabo (Formosa, mount.)
B3 - P.T.B.10 (India)
B2 - Mino-mochi No.1. (Japan, upl.)
B1 - Tjina (Small Sunda)
C3 - Gaisen (Japan, upl.)
C2 - Hu-tzu (Formosa)
C1 - I-kung-pao (Formosa)
D3 - R.T.S.27. (Frence Indo-China)
D2 - Macan Sapok (PhilipPine)
D1 - kokko-mochi (Japan, upl.)
E - Padi Atjeh. Cclebes, healthy)

Table 74. Varietal resistance of the leaves of different ages under different conditions.

Varieties	(I) Glass-houss experiments				(II) Wire-gauze house experim.		(III) Field experiments		
	A			B	C	D	E		
	a	b	c				a	b	c
Japan (Lowland)									
Shinriki	2 84	0.30	+++	A2			34.5	0.8x0.4	++++
Kameji				A2			19.8	0.8x0.4	++++
Aikoku				A2			18.0	0.5x0.2	++++
Asahi No. 2				A2		A2	9.5	0.6x0.2	++++
Mizuho	1.08	0.10	++	A2		A2	23.6	0.7x0.5	++++
Kinugasa-wase	1.30	0.20	++	A2	A3	A3	28.5	0.3x0.3	+++
Wase-ginbozu				A3		A3	8.5	0.3x0.2	++++
Ginbozu-okute				A3	A2	A3	11.0	0.8x0.3	++++
Iyo-omachi	1.56	0.25	++	A3		A2	6.0	0.6x0.2	++++
Benkei	7.33	0.30	++	A2			15.8	0.4x0.3	++++
Shinjyu No. 1				A3		A2	14.0	0.9x0.4	++++
Shinjyu No. 2				A1	A2	A3	8.9	0.4x0.2	++++
Hatsuhikari	15.33	0.25	+++	A3	A3	C3	9.9	0.3x0.2	++++
Ohine	1.60	0.20	++	A3	A2	A3	8.0	0.3x0.2	++++
Kidai-wase	7.80	0.20	+++						
Kidai No. 74	7.25	0.25	+++	A3	A2	A3	15.8	0.9x0.3	++++
Aikoku No. 3	1.33	0.10	++	A2	A2	A3	18.0	0.9x0.3	++++
Yoshino No. 1	2.50	0.20	++	A1		A2	5.9	0.3x0.1	+++
Tomikuni				A3	A1	A3	12.0	0.5x0.2	+++
Norin No. 1				A3	A2	A2	10.0	0.9x0.3	++++
Norin No. 6				A3	A2	A1	8.5	0.8x0.2	++++
Norin No. 8	5.29	0.15	+++	A2	A2	A2	13.0	0.4x0.2	+++
Norin No. 10	2.56	0.15	+++	A1		A2	7.6	0.6x0.3	++++
Norin No. 12	1.00	0.10	++	A2		A2	5.8	0.4x0.2	+++
Norin No. 13	2.78	0.20	+++			A2	16.5	0.3x0.2	++++
Norin No. 14	1.20	0 15	++	A3		A3	15.4	0.6x0.2	++++
Norin No. 15				A2		A2	5.8	0.8x0.3	++++
Riku-u No. 132	2.30	0.20	+++	A2		A2	8.9	0.7x0.4	+++
D 9	0	—	—	A2		A3	19.0	0.4x0.2	+++
NC No. 4	0.80	0.10	+	A3		A2	4.5	0.4x0.2	+++
Japan (Upland)									
No-shinriki				C1	D2	C1	3.0	0.4x0.2	++
Gaisen				C1	D2	C1	3.2	0.4x0.2	+
Kahei				B3	D2	C1	4.5	0.7x0.4	+++
Kumaki	0	—	—	C1		D2	3.5	0.6x0.3	+++
Hujizo-mochi	0	—	—	C1		D2	3.5	0.6x0.3	+++
Hideri-shirazu	0	—	—	A3	A3	A3	4.1	0.6x0.2	+
Riku-u No. 22	1.72	0.15	++	C2			2.0	0.4x0.1	+
Tochigi-urazu No.1	0	—	—				3.0	0.8x0.4	+
Kinsei-jun No.1	2.89	0.20	++	A2	A1		1.5	0.5x0.3	++
Yoshino-mochi No. 114	0	—	—	A3	A3	A3	3.6	0.8x0.3	+++
Kumamoto No. 1	0.10	0.10	—	A2	A2		12.5	0.8x0.4	++
Yonoyuki-mochi No.35	0	—	—	A3	A3	A1	14.0	0.4x0.2	+
Hukutomi				B1	D2		1.2	0.5x0.2	+
Kokka				A3	C1	A3	3.0	1.0x0.2	++
Urazo				C1	D1	C1	8.0	1.0x0.2	++
Hirayama				C1			4.0	0.3x0.2	++
Ohata				D1	C1	D1	2.2	0.5x0.2	+

Kokko-mochi				D1	C1	C1	4.3	0.5×0.3	+++
Iwate-ryo-on No. 1				D1		C2	5.6	0.5×0.2	+
Norin-mochi No. 1				D1		C1	7.0	0.7×0.2	+++
Norin-mochi No. 5				C1		D1	1.3	0.4×0.2	+
Mino-mochi No. 1				B2		D1	4.2	0.5×0.2	+++
Kagoshima-hakamuri No.1				C1		C2	7.6	0.4×0.2	++
Formosa ("Horai")									
Taichu Sp.No.6	5.78	0.25	+++	A3		A3	33.4	0.8×0.3	++++
Taichu No. 65	5.00	0.30	+++	A3	A3	A3	18.0	0.8×0.3	++++
Taichu No. 150	2.10	0.20	++	A2	A3	A3	7.6	0.4×0.3	+++
Taichu No. 153	1.05	0.15	++	A2		A1	9.6	0.3×0.2	+++
Taichu No. 155				A2	A3	A2	10.6	0.3×0.2	+++
Taichu No. 157				A1			8.6	0.5×0.2	+++
Taichu No. 160	1.89	0.20	++	A2		A3	11.0	0.3×0.2	+++
Taichu No. 161				A2			6.8	0.3×0.2	+++
Taichu No. 162	1.50	0.15	++	A1	A2	A2	5.6	0.3×0.2	+++
Taichu-mochi No. 46.	7.90	0.25	+++	A3	A2		25.8	0.7×0.4	++++
Taichu-mochi No. 59				A3	A3	A3	16.9	0.5×0.3	++++
Taichu-mochi No. 60				A3		A3	20.0	0.4×0.3	++++
Taichu-mochi No. 62	4.10	0.20	+++	A2	A3	A2	11.0	0.4×0.3	++++
Taino No. 47	3.15	0.20	++	A3	A3	A1	38.1	0.4×0 2	++++
Taino-mochi No. 7				A2		A3	24.1	0.6×0.2	++++
Taihoku No. 7	0.90	0.10	+	A3		A2	3.5	0.3×0.1	++
Taihoku No. 9							4.1	0.3×0.2	+
Shinchiku No. 4	2.58	0.20	++				9.1	0.7×0.4	+++
Shinchiku No 8				A2	A3		12.1	0.7×0.4	+++
Kanan No. 2	2.50	0.15	+	A2			5.1	0.5×0.2	+++
Kanan No. 8	1.80	0.15	+	A2			7.2	0.5×0.3	++
Takao No. 10	1.10	0.10	+				5.1	0 3×0.1	++
Takao No 11							3.2	0.3×0.1	++
Takao No. 18							4.3	0.3×0.1	++
Formosa(End em. Plain)									
U-tsein	0	—	—	C1	C2	A2	0.5	0.1×0.1	—
Peh-mi-fen	0	—	—	C1	C3	B2	2.1	0.5×0.3	±
Pai-ku	0	—	—	B1	D2	B2	4.0	0.4×0.2	±
Tsing-kao	0	—	—				0.5	0.2×0.2	—
Niao-iao	0	—	—				1.2	0.3×0.2	—
Sien-lo	0	—	—				0.3	0.8×0.4	—
Shiang-chiang	0	—	—	D1	D2	D1	0.5	0.5×0.2	—
Man-tzu	0	—	—	D1	D2	D2	0.3	0.4×0.1	—
Ta-hua	0	—	—				1.0	0.5×0.2	—
Ngan-tzu	0	—	—	D1	C2		0.3	0.5×0.2	—
Lin-mu	0	—	—	C2	B1	B3	4.1	0.3×0.1	—
Eh-ia-chan	0	—	—				1.3	0.2×0.1	—
Tsing-kuo-chan	0	—	—	C2	B1	C3			
Keh-tsu	0.06	0.10	—	E	E	D3	2.0	0.3×0.1	—
Ti-chioh-u-tzien	0	—	—	E			0.3	0.4×0.1	—
I-kung-pao	0	—	—	C1	C2	D2	3.0	0.3×0.1	±
Tian-rai	0	—	—	C1	D1		2.0	0.3×0.2	—
Min-tung	0	—	—	B1	C2	B1	0.4	0.5×0.2	—
Hu-tzu	0	—	—	C2	C3		1.9	0.3×0.1	—
Peh-kuh-chin-hou	0	—	—	B1	D2	D2	1·6	0.4×0.2	—
Peh-mi-chin-hou	0	—	—	E			3.1	0.4×0.2	—
Pai-ku-chien-yu				B2					
U-ku				C2					
Towan-tee-foa-ru				C2					
Formosa(Mount.,lowland)									

Tobura	0.06	0.20	—	C1			3.0	0.9×0.4	—
Tsubura	0	—	—	E			3.1	0.5×0.2	±
Payai-patosu	0	—	—	B1			0.6	0.4×0.2	±
Pa-azu-shibiri	0	—	—	C1			3 4	0.3×0.2	±
Taimo							5.0	0.2×0.1	—
Karas-karas-rankaf	0.62	0.10		D1	D1	C1	1.3	0.3×0.1	—
Patsu-rankas	0	—	—	C1	D1	D1	0.4	0.2×0.1	—
Nawayao	0	—	—	C1	D1		0.6	0.2×0.1	±
Nata-pasume	0	—	—		D1		0.8	0.2×0.1	—
Pa-azu-dobusu	0	—	—				1.1	0.3×0.2	—
Pattos	0	—	—				0.3	0.3×0.1	—
Possiam							0.2	0.3×0.1	—
Formosa(Mount.,upland)									
Sakura	0	—	—	A1	C2	B2	0.5	0.4×0.2	—
Fukeru-pagai	0	—	—				1.0	0.4×0.2	—
Pohotzu-taiyar	0	—	—	A1	D2	D2	0.1	0.4×0.2	—
Glus	0	—	—	A1	A1		3.5	0.4×0.3	—
Ha-asuko-tayur	0	—	—	B1	B2		5.1	0.7×0.4	±
Bohai	0.17	0 10	—	B1			6 0	0.4×0.3	—
Komonawai	0.38	0.15	—	C1		D3	1.5	0.6×0.2	—
Paiya-uttur				D2		B3	6.0	0.3×0.1	—
Tahoh-nin	0	—	—	D1			0.3	0.4×0.2	—
Peris	0	—	—	D1		D1	1.0	0.4×0.1	—
Nashippai	0	—	—						
Nakaran	0	—	—		D2		1.0	0.7×0.2	—
Nakabo	0	—	—	A1	D2	A1	0.1	0.2×0.1	—
Erami No. 4	0	—	—	B2	D2		0.3	0.6×0.2	±
Erami No. 8							0.2	0.2×0.2	±
Mongolia									
Ta-tung-tsai-lai	0	—	—				6.9	0.6×0.2	±
Sui-luh-tsai-lai	0	—	—				3.2	0.4×0.2	±
Ta-mao-tao							9.0	0.4×0.2	±
Shouh-tsai-lai							4.1	0.4×0.2	±
Huen-shui-tao	0	—	—				4.1	0.4×0.2	±
North China									
Ta-Peh-mang	1.20	0.15	—	A1	A3		2.5	0.2×0.1	+
Hu-lo-tou	3.40	0.15	+	A1	A2	C3	12.1	0.7×0.2	+
He-nan-tiao	0.10	0.10	—				1.6	0.4×0.3	+
Middle China									
Tsao-siao-peh-tao	0	—	—				0.5	0.8×0.4	—
Mao-tsu-tou	0	—	—				1.6	0.7×0.3	±
Fei-lai-fung	0	—	—	A1		A3	0.3	0.2×0.1	—
Huang-tao				A1	A3	A3	0.5	0.4×0.2	—
Yie-wan-tao				A1	A3	A2	1.2	0.4×0.2	—
Chian-si-wan							0.3	0.4×0.2	—
Nan-chang-wan	0	—	—		C2		0	—	—
Lu-hwa-peh	0	—	—	A1	A3		6.5	0.8×0.4	+
Po-yang-tsao	0.01	0.12	—	C1	C2		0.9	0.4×0.2	—
Chin-sien	0	—	—	B1	D2		0.2	0.4×0.1	—
Hsu-chow No. 34	3.20	0.20	+	B1		A3	9.6	0.5×0.3	+
South China									

Tung-Kuan-yon-nien	0	—	—				8.6	0.5x0.2	++
Hsiang-Keng				B2		A3	3.2	0.5x0.2	++
Tseng-cheng-miao						A3	0.9	0.6x0.2	+
Chuh-nien-kuh	0	—	—	A1		A3	1.7	0 5x0.2	—
Fu-chow-ta-tsao				B1	B1		0.6	0.6x0.2	—
Tuan-tah-tsao							1.2	0.4x0.2	—
Tsao-shan-pei					B3		1.7	0.3x0.2	—
O-hou-tsao-chieu				A2	B1	B2	4.7	0.3x0.2	—
Kao-shen-kuang	0	—	—	B1		B1	5.0	0.3x0.2	—
O-hou-tsin-tsao	0	—	—	B1			4.9	0.3x0.2	—
Lien-chian-mi-tsao-tah	0	—	—	A2			6.5	0.3x0.2	—
Chu-tsao	0	—	—	C1					
Chin-tsao	0	—	—	C1			3.6	0.3x0.2	—
Chin-pang-nien	0	—	—	A2		A3	11.6	0.3x0.2	++
Kun-min-tsieh-huan	0	—	—	A2		B3	4.4	0.3x0.1	—
Tung-yang-tsao	0	—	—	A1			2.0	0.2x0.2	—
Hsiang-shan-sha-shang	0	—	—	C1			4.9	0.4x0.2	++
Sui-nuan-nuo-kuh							3.0	0.2x0.1	—
Sueh-hua-nien				C1	D3	C2	2.0	0.3x0.1	—
Ta-pu-kuen-tzu							4.5	0.5x0.2	++
Hai-yan-ta-nian							0.6	0.3x0.2	—
Peh-kuh-mih-miao							1 0	0.4x0.2	++
Hu-tao							4.1	0.3x0.2	—
Chin-feng-sueh				B1	D1	C2	8.2	0.4x0.2	++
Ing-teh-yang-nien							1.2	0.3x0.1	—
Ung-chow-sa-tao-tzu							1.2	0.3x0.1	—
Tung-kuan-nian-tzu							0	—	—
Peh-chao							4.7	0.3x0.1	—
Kan-mi							0.3	0.7x0.2	—
Yang-chuen-tao-nian							0.4	0.3x0.1	—
Tsin-yie-lu-chi-tsao				B1			0.3	0.3x0.2	—
Tsing-yie-tsao-tao				B2			0.2	0.2x0.2	—
Cheh-ta No. 676				C1		B2	1.2	0.3x0.2	—
Ning-yan-keng				B1	C2	B3	4.6	0.4x0.2	++
I-fung-tsao					D2		3.4	0 3x0.2	—
Tiso-yii-lan							0	—	—
Kuh-keng				B1		B1	2.0	0.6x0.2	—
Chien-mi				B1		D1	1.5	0.6x0.3	—
Chan-kuh				E	C2	C1	1.0	0.4x0.2	++
Philippine									
Apostol	0	—	—		D1	D3			
Guinangang	0	—	—				2.4	0.2x0.1	—
Kenurz	0	—	—	D1	D1		0	—	—
Ketan Kaetoeh	0.17	0.10	—	B1		C2	0	—	—
Kinan Kuda	0	—	—	C2	C3	B1	0.6	0.4x0.2	—
Inaposto!	0	—	—	E			0.3	0.4x0.2	—
Macan Caranglan				C2	C3	C3	0.1	0.2x0.2	—
Macan Menita	0	—	—	B2		C3	0	—	—
Macan Ramitad				C2		D3			
Macan Sapok				D2					
Macan Talipina				E	D3	D2			
Malagkit Sinoguing				D1			0.7	0.4x0.2	—
Takloban				C1	C3	B1			
Singapablo							0	—	—
Celebes									
Padi Anadara				E1		D1	0	—	—
Padi Asse Banda							2.1	0.3x0.2	—
Asse Lasse				B1			0	—	—

Asse Tjella				B3			0	—	—
Atje							3.5	0.4x0.4	—
Padi Pali	0	—	—	C2			1.5	0.3x0.2	—
Padi Barri				C2			0	—	—
Padi Bekka				C3					
Padi Bogo						C3			
Padi Bogo						B2	0	—	—
Bali Atjeh				E	D1	D1	0	—	—
Bene							0	—	—
Padi Denji Lare							4.0	0.3x0.1	—
Padi Hotjong				B3			0	—	—
Padi Kasalle				C3		C2	3.6	0.3x0.2	—
Padi Ladang	0	—	—				0	—	—
Linoetoeng	0	=	—				1.2	0.6x0.2	—
Maraya							1.5	0.6x0.2	—
Padi Pentjeng				C3		C2	2.6	0.4x0.2	—
Padi Pacloet Bolang				B3		B3	3.6	0.4x0.2	—
Poenot Hitam	0	—	—	C1		B1	0	—	—
Padja				C3			0	—	—
Padi Raockang							0	—	—
Sahe				C1			1.5	0.4x0.2	—
Padi Sake				C3		B2	0	—	—
Semoeran							0	—	—
Seratoes Hari				B2					
Tjina	0	—	—						
Lesser Sunda &Java									
Baah	0	—	—	B3	C3	B3	0	—	—
Boegi Inda	0	—	—				0	—	—
Karike	0	—	—			B3	0	—	—
Keke Kala	0	—	—				0	—	—
Keke Modja	0	—	—	B3	C2		0.6	0.3x0.2	—
Keta Boera				B3		B3			
Lako	0	—	—	B3	D2	B3	0	—	—
Djogading Menengah					B3		19.0	0.3x0.1	—
Lendak Kesaming	0	—	—			B3	5.0	0.2x0.1	—
Mojor	0	—	—				2.5	0.6x0.3	—
Manggarai	0	—	—	B2		B3	3.6	0.4x0.2	—
Montja Koempoe							0	—	—
Montja Mac							0.2	0.4x0.2	—
Poetih Menok Don	0	—	—				3.6	0.4x0.2	—
Brondol Poetih				C2		C2	8.2	0.4x0.2	—
Naggegang	0 20	0.20	—				5.6	0.3x0.1	—
Soro						B2	0	—	—
Tjina				B1			0	—	—
Mojor							0	—	—
Manggarai							4.8	0.3x0.1	—
Montja Mangge							0	—	—
Mentjel				C1		C3	0	—	—
Monda							0	—	—
Montja							0	—	—
Poetih Menok Don						B3			
Tjina B.						D1			
Padi Boenar							0	—	—
Padi Seri Mahi	0	—	—	B3	B3		0	—	—
French Indo-China									
BaSao	0	—	—	C1	D1	C1	0	—	—
Danke	0	—	—				0	—	—
Di Tam Muon							0	—	—

Gian Hen	0	—	—				0	—	—
Gian Cao	0	—	—	D3	C2	C2	0	—	—
Gian Lum				D2		D2	0.5	0.5×0.2	—
Gian Muon	0	—	—			D2	0	—	—
Gian Nghe	0	—	—	C2	C2	D2	0	—	—
Giong Trang	0.30	0.20							
Gie Hien	0.30	0.10		B3		B3	0	—	—
Gie Noi	0	—	—				0	—	—
Hop	0	—	—				0	—	—
Lun Chim				B2	A3	B3	0	—	—
Tam Cau				C3	B2	B3	1.2	0.3×0.2	—
Tam Muan						B3	2.0	0.3×0.2	—
Tam Nhoon Tamlun					B1	C3	0	—	—
Tam Xoam	1.00	0.15	—			B3	0	—	—
R. T. S. No. 11				C3	D2	D3	0	—	—
R. T. S. No. 14						D3	0	—	—
R. T. S. No. 16	0	—	—				1.3	0.8×0.2	—
R. T. S. No. 17	0	—	—			C2	1.0	0.3×0.2	—
R. T. S. No. 20	0	—	—				0	—	—
R. T. S. No. 23	0	—	—		D1	D3	0	—	—
R. T. S. No. 24	0	—	—	D1	B1	B2	0	—	—
R. T. S. No. 27	0	—	—	D3	D1	C3	0	—	—
R. T. S. No. 28	0	—	—	B2	D2	D2	0	—	—
R. T. S. No. 29	0	—	—	B2	C2	C2	0	—	—
R. T. S. No. 30	0	—	—	C3	D2	D2	0 2	0.2×0.1	—
Malay									
Meyong						D2	1.2	0.2×0 2	—
Siam									
Kao Tod Long	0	—	—						
Poung Ngeun	0	—	—				0	—	—
Plaiuk Kai							1.1	0.2×0.1	—
Pin Keow	0	—	—						
Mali Tong Bow				B1			1.1	0.3×0.1	—
Mali Ong							0	—	—
Emata				C2	C2	D2	0.6	0.3×0.1	—
Letywezin	0	—	—	B3	D3	B3	0	—	—
Ngatsin	0	—	—				2.0	0 3×0.1	—
India									
Gurdoi							0.7	0 3×0.1	—
Heenati	0	—	—	C2	D2		0	—	—
Indeasal	0	—	—	B1	D1		0	—	—
Mugi							0	—	—
Pacchai Perunel	0	—	—				2.6	0.4×0.2	—
Pweabini	0	—	—				0	—	—
Coimbatore No. 7							0	—	—
A. D. T. No. 4							2.0	0.2×0.1	—
A. D. T. No. 14							2.4	0.3×0.1	—
D. T. B. No. 8							0.4	0.3×0.1	—
Vallai Perunel	0	—	—	D2	D2	B2	0	—	—
P. T. B. No. 7				C2		C2	0	—	—
P. T. B. No. 9				D1	D1	C1	0	—	—
P. T. B. No. 16				C1			0	—	—
Europe, America, etc.									
Keau N525(U. S. S. R.)	A			A2			0	—	—

Bomba(Europe)				A2		A3	2.0	0.6×0.2	++
Red Rice(East Africa)	0	—	—	C1	C2	C3	1.0	0.4×0.2	—
Louisiana Non-bcard	0	—	—	A2	D2		1.0	0.3×0.1	++
Blue Bose (Europe)	1.35	0 20	++	A2		A2	2.2	0.4×0.2	++

From the experiment B of table 74, the varieties endemic to the various regions are classified as follows (vid. table 75), exclusively based upon the infection types.

Table 75. Number of varieties endemic to the different latitudinal regions classified according to the infection types.

Habitat(Type)	No. of var.	Infection types														
		A			B			C			D			E		
		3	2	1	3	2	1	3	2	1	3	2	1			
Japan (Lowland)	28	12	13	3												
Formosa ('Horai')	20	7	10	3												
Japan (Upland)	22	4	2		2	1	1		2	6			4			
Formosa (Mount., Upland)	11			4		1	2			1		1	2			
Formosa (Mount , Lowland)	8						1			5			1		1	
Formosa (Plain)	19					1	3		4	5			3		3	
North China	2			2												
Middle China	7			4			2			1						
South China	23		4	2		2	8			6			1			
Philippines	11					1	1		3	1		1	2		2	
Celebes	16				2	2	1	4	2	3					2	
Great & Lesser Sunda	9				5	1	1		1	1						
French Indo-China1	12				1	3		3	1	1	2	1				
Siam & Burma	3				1		1		1							
India	7						1		2	2		1	1			
Europe, America, etc	5		4							1						

As shown in tables 74 and 75, in general most of the varieties native to the temperate regions are very suscepitble in comparison with the tropical varieties, and this tendency is more remarkable in the adult plants than in the seedlings. Some of the latter seem to be equally susceptible as in the case of the former, so far as the number and size of the lesions are concerned, although the lesions of many of the latter are brown in colour due to the wides necrotic zone extending over the venenate and disintegrated zones with a scanty sporulation (infection type B), whereas those of the former are typically fusiform in shape and dark grey in colour due to the predominance of the disintegrated zone with a vast number of conidia. Kawamura (1940) pointed out that there is a distinct difference of resistance among the species of oryza different in their chromosome number. However, as shown in the above, the grade of resistance of the temperate and tropical varieties, similarly belong to the same species, O. sativa, is rather divergent, and it is difficult to make a distinction between these two cases. It must be admitted, however, that the above-mentioned relation between temperate- and tropical varieties is merely of a general tendency. The variety-groups which are separated according to the habitats shown in table 75 can be classified into the following three categories.

(1) The variety-groups, all of which show infection-type A. Variety-groups of Japanese lowland, "Horai" (Japanese lowland type bred in Formosa), and North China are involved, herein.

(2) The variety-groups which reveal a striking intervarietal variation as regards the infection-type (*i. e.* from A to F).

Variety-group of Japanese upland, Formosan upland, (in the mountain regions), Middle & South China, Europe & America are involved.

(3) The variety-groups which exhibit a moderate intervarietal variation as regards the infection type (*i.e.* from B to F). Variety-groups of Formosan endemic (except upland), Philippines, Celebes, Great & Lesser Sundas, French Indo-China, Siam, Burma, and India are involved.

So far as the present experiments are concerned, all the Japanese

lowland varieties showed almost similar infection type (A - type). This fact seems to coincide with the opinion of Shibuya & Oka (1944) who interpret from the growth habit of the young seedlings that the Japanese lowland group is consisted of the closely related varieties which might have been originated from certain allied genes. On the other hand, the Japanese upland group contains the varieties different in the infection type as mentioned above, and this seems to endorse Hamada's (1935) historical research that this group contains a considerable number of varieties introduced from China after the mediaeval ages. Since the pioneer work of Kato *et al.* (1930, *et passim*) who divided the cultivated varieties of rice plants into two subspecies, "*japonica*" and "*indica*", basing upon the morphological and serodiagnostic characters and also on the sexual affinity, his theory has been supported by some other workers, though there are a considerable divergence. In that paper, they stated that the subspp., Japonica and Indica, are distributed over the temperate and tropical regions, respectively, and these two are contiguous to Middle China. According to the author's present study, the variety - groups of Middle China, South China. Formosan upland of mountain regions, etc. can be invariably included to the group 2, so far as the infection type is concerned, but it is of almost no doubt that these variety - groups are mixed with the varieties different in their genetic resistance. The same may be true with the group 3, though the range of variation in the varietal resistance is narrower than in the group 2. In consideration of the fact that the intervarietal variations in the infection type of each variety - group are considerably different, except the Japanese lowland group, it is nothing but a general tendency that the varieties endemic to the temperate zone are more susceptible than the tropical ones, hence the classification of varieties based upon the infection type may not always agree with Kato's theory.

B. Varietal Resistance of the Neck of Ears and the Node of Culms

The neck - and node - blast resistances of the varietes indigeneous to

the different latitudinal regions was tested with the use of varieties employed for the experiments on the varietal resistance of leaves. In 1947, the experiments were repeated under the different conditions of soil moisture and nitrogen supply at the different seasons so as to avoid the errorneous determination of the varietal resistance due to "disease escaping". In all the experiments, the plants were allowed to the natural infection, since the employed varieties could not be uniformly infected by means of the artificial inoculation due to the difference of their heading time and the rapidity of maturity. The grade of infection was compared at the maturity stage of the respective variety by means of counting the percentage of the neck, the rachis as well as the rachilla of ears, and the node of culms affected by the disease. Likewise the experiments on the varietal resistance of leaves, the symbols marked in the series of the following experiments coincides with those shown in the respective column of table 76.

(I) Experiments in the garden-beds of sandy loam encircled with the concrete-wall of 2.5 x 32.0(m.). Ten hills※ were grown for each variety with nitrogen twice as much as the ordinary amount.

(A) The first experiment (Sowing, Jan. 15; transplanting, Feb.27; maturity, June - Aug.). The beds were kept under the upland condition by means of the occasional irrigation. Only the infection of the neck of ears (a) and node of culms (c) was examined.

(B) The second experiment. The growth duration of the plants was same as in the former, but the beds were kept under the flooded condition. Examination was made on the infection of the neck(a), the rachis and the rachilla(b) and the node of culms(c).

(II) Experiments in the paddy field

Twenty hills were grown for each variety at the different seasons under the field condition, nitrogen fertilizer being given triple as much as the ordinary amount.

(C) The third experiment (Sowing, Jan. 15; transplanting, Feb, 26; maturity, June - Aug.). The infection of the neck(a), the rachis and the rachilla(b), and the node of culms(c) was examined.

※ A single seedling was transplanted per hill.

Table 76. Varietal resistance of the different portions of ears and nodes of culms of rice plants grown under different environmental conditions.

Varieties	(i) Bed culture					(ii) Paddy field								
	(A) Upland		(B) Flooded			(C) Sown: Jan.			(D) Sown : Feb.			(E) Sown : Mar.		
	(a)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)
Japan (Lowland)														
Shinriki	39.3	24.6	25.4	28.3	55.1	9.8	8.3	41.4	20.4	10.5	9.9	12.4	9.5	21.2
Kameji	7.0	28.1	37.1	24.2	53.2	3.3	3.7	50.0	4.1	6.1	57.1	7.2	19.0	17.1
Aikoku	6.0	55.8	23.9	16.9	49.3	2.0	8.9	63.4			77.4	12.5	9.3	33.3
Asahi No.2	19.8	14.7	20.8	21.8	20.8	1.2	16.9	27.9	5.6		34.4	6.0	9.5	25.0
Mizuho	3.8	4.5	38.3	30.9	29.6	11.3	1.7	13.0	6.8	2.7	25.2	9.5	12.7	41.3
Kinugasa-wase	11.5	23.0				10.1	15.9	50.7	18.3		64.6	10.8		43.2
Wase-ginbozu	30.3	23.2				38.3	18.1	27.7	14.6		54.9	16.7		61.9
Ginbozu-okute	34.4	26.1				11.7	9.9	22.5	9.1	22.7	71.2	24.8		34.4
Iyo-omachi	31.3	37.3	10.4	22.9	25.0	4.7	4.7	29.4	11.4		25.0	9.7	16.7	44.4
Benkei	5.9	7.3				2.2	39.7	49.3	8.6	13.4	29.6	33.8	19.1	36.0
Shinjyu No.1	48.0	11.0	10.3	25.4	29.4	7.1	26.2	38.9	16.5	2.5	17.7	14.9	29.8	15.8
Shinjyu No.2	35.0	20.8				14.9	28.1	16.5	43.5		83.6	19.4	19.4	37.0
Hatsuhikari	22.8	18.4	60.0	7.7	49.2				20.9		62.7			
Ohine	5.9	8.2	38.7	19.4	48.4	9.7	11.7	39.8	21.2		50.6			
kinai No. 74	17.0	13.8	13.5	11.9	16.7	5.7	17.0	51.9	4.6	13.2	25.0	8.5	9.4	24.8
Aikoku No. 3	27.7	27.7	16.8	18.4	22.4	14.5	35.5	37.0	13.3		49.1	24.1		47.3
Yoshino No.1	2.4	6.0	30.3	14.5	48.7	3.4	18.0	41.0	13.5	12.1	47.5	11.3	44.4	13.9
Norin No.1	21.7	88.5	21 6	11.2	18.4	11.1	11.9	43.0	26.7		34.1	5.0		41.7
Norin No.6	5.2	7.5	16.4	15.7	11.9	12.5	39.1	9.4	7.4		47.1	19.5	43.1	17.1
Norin No.8	39.4	12.8	57.5	23.9	50.4	57.8	36.6	15.5	21.4		50.4	37.9	10.6	42.4
Norin No.10	74.2	20.5				31.0	18.3	88.7				25.0	14.8	41.4
Norin No.12	47.7	7.4	6.4	40.9	42.7				10.3		47.1	13.6	29.4	1.8
Norin No.13	29.7	9.1				0.8	1.9	11.7	1.5		75.0	30.6	11.6	19.0
Norin No.14	23.0	23.0	25.9	18.8	24.1	2.8	3.9	11.7				17.6		45.9
Norin No.15						5.5	26.2	20.0	5.7		54.6			
Riku-u No.132	20.3	27.0	3.1	9.2	13.9	21.9	32.0	16.4	16.2		45.6	8.6		42.0

D 9	21.8	36.5	14.6	24.5	32.5				43.5	8.9	54.8	14.3	13.1	32.6
NC No.4	10.9	12.0	3.9	10.8	31.4	10.5	6.8	17.9	7.8	14.9	55.8	3.6	10.7	15.5
Kirishima	6.9	33.5												
Nagara-wase	38.3	75.3							20.0		100.0			
Tomikuni	17.3	38.7												
Japan (Upland)														
Noshinriki	1.7	4.4				1.9	3.8	13.2	0	5.3	16.8	9.1	6.1	59.1
Gaisen	1.0	16.0										14.9		60.8
Kahei	1.3	30.0	43.3	32.5	67.5							11.6	8.1	60.5
Kumaki	6.5	24.4							1.1	4.4	38.5	10.3	11.5	73.1
Hujizo-mochi	13.9	3.5				2.3	3.5	14.9	0	0	26.9	15.5	13.1	22.6
Hideri-shirazu	13.3	18.4	66.7	49.2	79.4							23.0		45.9
Riku-u No.22						0	1.9	11.5						
Kinsei-jyun No.1	12.8	14.2				1.9	31.1	50.5	9.0	18.6	22.8	13.3	25.3	38.6
Yoshino-mochi No. 114	4.8	10.5				6.0	16.0	58.0				11.8		41.2
Kumamoto No.1	13.3	12.1	13.4	40.8	24.2	25.0	19.4	39.5	9.0	8.1	44.1	19.7	11.8	23.7
Yonoyuki-mochi No. 35	5.7	24.3	14.1	40.2	35.9	23.8	26.2	28.6	24.1		96.6	27.7		85.1
Fukutomi	4.8	31.3	25.6	8.5	46.3	10.5	3.0	15.7	2.7	4.6	43.6	15.9	29.3	4.9
Kokka	3.5	17.7										4.5		66.7
Urazo	4.4	55.5	30.1	15.7	75.9	11.1	30.6	43.1	10.0	16.3	52.5	13.6	16.1	77.8
Hirayama	1.0	30.2										10.2	25.4	55.9
Oh-hata	12.9	43.3							4.2		34.7	18.6	27.9	46.5
Kokko-mochi	9.8	7.8	35.8	32.1	53.1	1.3	1.3	30.3	2.1	1.4	44.4	5.7	13.6	44.3
Iwate-ryo-on No.1	11.9	11.9				6.8	5.7	22.7	9.1	4.6	37.9	14.6	32.7	78.2
Norin-mochi No.1	26.3	11.6				2.0	4.1	10.2	0	3.5	66.3	14.1	28.1	81.3
Norin-mochi No 5	23.3	5.8	33.3	6.0	33.3	6.5	2.6	10.4	2.8		43.0	18.3	9.9	78.9
Mino-mochi No.1	98.0	17.7				1.2	4.9	9.9	0	0	33.3	10.7	15.5	50.0
Kagoshima-hakamuri No.1	10.9	22.7				3.9	9.6	79.8	5.4	0	31 5	18.0	20.5	47.4
Formosa "Horai")														
Taichu Sp No.6	16.5	13.8				5.8	6.5	81.2	11.0	13.6	13.6	13.0	15.4	17.9
Taichu. No.65	6.3	11.5	4.4	24.6	47.8	1.1	6.7	12.2	11.3	28.3	58.5	28.1	9.6	30.7
Taichu No.150	13.5	26.9	4.8	6.7	31.7	2.4	12.1	26.7	0		67.3	13.8	27.7	6.4
Taichu No.153	10.6	19.2	2.5	13.2	16.5	10.6	19.5	18.7	3.1	4.7	52.1	14.1	14.1	42.2

Taichu No.155	3.1	13.9	13.3	0	8.6	8.6	5.1	32.5	1.2	3.0	49.4	11.0	34.1	22.0
Taichu No.157	9.4	11.8	23.6	3.3	37.4	1.2	10.1	54.4	0.9	15.1	51.8	14.7	18.1	67.2
Taichu No.160	8.1	46.0	17.3	0	3.9				2.9	6.9	36.3	11.4	15.4	34.1
Taichu No.161	0.9	43.9	22.0	1.7	32.2				5.7	9.0	25.4	15.4	26.9	
Taichu No.162	10.5	21.9	14.9	12.3	36.8	1.0	1.0	13.9	3.9	4.7	52.3	16.7	40.5	40.5
Taichu-mochi No.46	13.3	8.9				3.1	0.8	6.1				17.9	21.7	15.1
Taichu-mochi No.59	5.6	9.6	6.7	16.7	13.3	14.0	7.5	58.9	11.4	10.6	47.7	14.0	18.3	84.9
Taichu-mochi No.60	9.0	32.6	18.8	0.9	9.4	8.3	2.8	26.6	2.3	4.7	14.0	17.4	23.9	6.5
Taichu-mochi No.62	12.9	15.8				13.7	10.3	53.9	21.3	14.2	95.3	19.3	14.7	42.2
Taino No.34	30.0	44.2	20.8	14.2	21.7	15.7	9.9	38.8	23.7	23.7	4.2	25.6	21.0	64.7
Taino No.38	5.9	22.1	20.4	6.5	12.0	8.6	10.7	16.5	14.3	12.8	59.4	59.8		72 0
Taino No.41	13.3	23.6	11.0	3.5	11.8	6.3	37.7	59.7	24.6	6.3	53.9	9.8	17.1	30.9
Taino No.40	14.4	23.0	14.5	12.0	21.4	12.7	14.5	48.2	6.2	9.2	39.2	19.6	9.3	21.6
Taino No.42	9.3	18.5	4.9	7.8	6.9	8.5	13.0	10.2	29.7	7.0	64.1	20.5	42.3	82.1
Taino No.46	6.0	13.7	2.3	4 5	2.3	7.4	18.6	44.2	11.3	4.5	51.9	9.2	13.8	21.8
Taino No.48			2.9	3.8	7.6	9.1		62.0	11.5	14.2	67.3	21.6	32.0	34.0
Taino No.49	14.8	9.6	5.6	3.7	1.9	12.7	23.7	45.6	18.7	8.2	53.7	24.4	30.2	40.7
Taino No.50	11.2	44.9	12.5	5.9	23.9	7.1	25.2	93.3	12.1	10.6	19.7	4.5	23.9	25.0
Taino No.51	14.8	9.6				6.0	16.2	12.8	0.8	7.4	43.0	14.4	30.8	19.8
Taino No.52	15.2	53.6	28.6	11.8	44.5	1.7	3.7	6.0	29.5	14.8	47.0	10.5	9.6	73.7
Taino No.53	10.5	11.4	13.0	11.1	18.3	5.9	11.8	39.5	17.3	9.4	42.5	34.2	15.3	67.6
Taino No.54	7.8	13.9	7.9	4.0	23.7	4.0	24.7	33.5	11.0	9.0	51.7	28.6	35.2	44.0
Taino No.55	13.0	24.4	9.2	13.8	23.7	3.5	12.1	21.8	30.7	19.7	38.7	30.9	22.3	45.7
Taino No.47	4.7	14.9	5.8	1.5	2.9	5.9	11.8	10.5	9.3	10.0	3.6	7.3	10.6	11.9
Taino-mochi No.7	18.8	35.3	19.8	6.9	35.3	2.9	4.9	66.0	7.7		70.2	18.7	25.3	26.3
Taihoku No 7	3.9	17.3	10.6	3.5	20.4	7.1	9.5	29.4	9.4	14.2	33.1	9.4	11.1	34.2
Taihoku No.9	17.4	25.4	10.3	4.4	9.6	10.7	5.7	19.5	4.8	3.2	2.4	8.5	14.9	1.4
Taihoku No.12	7.3	29.0	15.1	5.0	9.2	2.3	17.2	26.1				4.8	10.8	52.9
Taihoku No. 2	16.0	24.4	11.2	7.8	25.0				11.8	5.9	66.7	24.8		55.2
Taihoku No.13	1.7	22.0	27.4	8.9	20.2	6.7	13.4	53.0	10.6	2.8	38.0	5.7	12.3	50.9
Taihoku No.22	13.0	8.3	13.9	10.9	24.8	7.4	26.3	32.1	58.6	25.2	64.9	25 0		33.3
Taihoku No.127	14.0	14.7	15.9	7.5	43.9	6.0	27.5	50.5	27.5	35.2	73.6	49.2		88.9
Taihoku No.177	14.2	23.1	14.3	11.6	22.3	4.0	6.3	9.7	22.3	8.7	36 9	12.2	8.2	22.4
Shinchiku No.4	17.0	37.5	4.0	7.3	25.8	8 2	3.3	45.9	14.8	20.5	69.7	9.0	38.7	75.7
Shinchiku No.8	12.0	23.2	14.0	1.5	20.6	19.0	3.4	16.3	13.3	6.3	37.8	7.6	37.0	44.5
Shinchiku No.5	3.5	11.3				10.3	14.2	82.8	10.7	19.3	50.7	12.5	13.6	45.5

Shinchiku No.7	2.7	27.3							12.0		53.4	19.1	34.0	27.7
Taichu No.158	3.0	13.0	7.8	0.9	17.4				3.5	8.5	36.2	3.1	27.6	7.1
Taichu No.159	17.6	63.7				6.3		64.3	4.4	8.9	34.5	7.1	11.2	57.1
Kanan No.2	2.5	9.3	21.7	1.0	1.0	3.3	0.7	13.8	3.1	6.2	40.2	9.0	7.2	35.1
Kanan No.8	12.4	17.8	18.0	0.8	2.3	14.2	18.9	87.7	2.2	4.3	77.4	9.4	14.1	30.5
Kanan No.9	7.6	8.9	19.1	6.4	8.2	19.9	12.4	25.7	23.2	11.6	52.9	19.2	19.2	70.2
Kanan No.11	14.5	4.8	8.2	4.1	3.1	18.8	23.6	41.9	17.6	6.4	30.3	10.8	11.8	37.6
Kanan No.12	5.6	5.6	4.2	1.0	4.2	7.8	5.4	33.5	12.5	4.7	50.8	12.5	11.5	43.3
Kanan No.13	7.7	17.3	9.6	4.8	7.2	0	2.7	11.5	4.9	0.8	49.6	12.1	6.9	41.4
Kanan No.14	9.7	2.2	0	0	5.5	5.6	6.5	49.2	12.2	3.8	42.7	1.8	7.1	2.7
Kanan No.20	53.3	56.7	17.2	15.2	49.5	12.5	18.1	43.1	11.1	14.3	65.1	14.5	19.4	24.2
Kanan No.25	5.0	26.7	10.0	13.6	38.3	11.7	19.4	57.3	21.0	9.0	45.0	38.9	13.0	33.3
Kanan No.10	26.2	27.7	21.4	0	8.7									
Takao No.10	6.1	20.3	14.3	3.2	8.7	2.3	23.6	75.3	6.7	12.4	73.0	10.9	8.0	38.7
Takao No.11	16.8	22.4												
Takao No.12	5.0	1.0	12.0	2.2	29.4	5.7	6.5	16.4	4.4	10.5	21.9	8.7	7.2	26.1
Takao No.13	1.7	7.8	13.7	0.8	25.8	0	2.4	21.2	7.0	5.2	35.7	15.4	12.0	31.6
Takao No.16	3.6	29.1				1.6	6.4	39.2	4.7	7.0	43.4	15.1	26.1	51.3
Takao No.18	3.6	40.6	0	0.8	4.6	0.5	6.8	56.3	4.8	11.1	50.8	8.9	18.5	19.4
Karenko No.5	15.4	27.1	30.4	21.6	40.7	19.4	24.5	79.9				7.2	24.7	48.5
Formosa (Native, lowl.)														
Utsien	6.3	9.8	12.5	5.7	20.5	11.4	10.1	13.9	5.9	2.5	44.9	4 8	2.4	28.6
Peh-mi-fen	15.0	20.0	27.5	6.6	42.9	0.9	5.5	33.6			80.7			
Pai-ku			19.5	10.4	32.5	0	0.7	59.1			56.0	0		85.0
Shuang-Ching						10.0	5.0	40.0	36.3		88.7			
Ta-hua	8.8	35.3	23.1	15.4	52.8	31.3	22.3	53.6						
Lin-mu						36.4	50.0	0						
Uh-rwan-tzu	3.2	11.6	19.4	12.9	40.9				5.4		91.1			
Tsing-kuo-chan						0	0	21.4						
Ti-chich-uh tzien	1.0	0												
I-kung-pao	13.8	17.5				13.2	13.2	57.0						
Pai-ku-chien-yu	16.7	34.5				52.2	26.1	60.9	13.6	9.1	42.4	2.6	5.1	82.1
U-ku	1.0	5.1	9.5	10.3	56.4	9.8	12.1	48.6						
Towan-kang-foa-ru	4.3	11.2	5.6	2.4	23.0	3.1	3.1	32.3				38.9		94.4
Formosa (Mount., lowl.)														

Tobura													31.4	20.0	77.1
Tsubura	0	1.6				15.6	37.5	15.6							
Taimo	31.0	21.8				39.1	78.3	47.8							
Karas-karas-rankaf									12.0	24.0	0				
Nawayao						3.1	12.3	36 9							
Nata-pasume						8.7	13.0	17.4	31.0	17.2	20.7				
Pattos	12.5	58.3	23.2	17.6	51.9	10.2		40.8	8.0		52.0				
Formosa(Mount, upl.)															
Fukeru-pagai	71.6	26.5	30.2	23.0	49.2	20.7	18.1	94.0	9.1		8 9.4		7.1		93.8
Pohotzu-taiyar	5.3	20.0				1.3	0	58.7							
Glus						15.6	15.6	84.4							
Ha-asuko.tayur	5.3	20.0							11.8		38.2				
Bohai	2.6	46.2				7.3	43.6	100.0	20.9		60.5		2.8		100.0
Komonawai						11.7	41.6	33.8	18.4	19.5	19.5				
Paiya-uttur									18.8	81.3	12.5				
Tahohin						9.9	9.2	51.1	0	0	41.5				
Peris	3.1	0.8				2.5	13.3	79.3	14.3		53.1		21.2	15.2	18.2
Nakaran						26.7	80.0	60.0	28.6	7.1	0		3.2	19.4	0
Nakabo	12.8	56.4	16.5	5.4	9.5	7.5	5.4	26.5	9.4	12.8	86.3				
Erami No.4	23.9	15.9				26.7	46.7	40.0	51.2	19.5	82.9				
Erami No.8						8.3	9.4	39.6	7.6	18.2	34.8				
Mongolia															
Sui-luh-tsai-lai													4.3		71.7
North China															
Ta-peh-mang						13.0	15.2	64.1	7.5		43.4		5.1	39.7	41.0
Hu-lo-tou	33.1	31.8	58.1	62.9	80.0	4.4	0	77.4	16.4		100.0		17.3	13.5	30.8
Middle China															
Tsao-siao-peh-tao	20.7	59.8				7.9		100.0	3.7		100.0		17.7	11.3	88.7
Mao-tzu-tou									4.7		100.0		11.5		59.6
Fei-lai-fung	8.7	3.4	22.2	15.4	16.2	4.3	6.8	91.4	0	10.9	51.6		8.9	10.4	4.4
Huan-tao			11.2	35.7	66.3	8.2	2.7	44.5	10.2	15.9	40.9		16.7	7.7	17.9

Yie-wan-tao						0	0	48.8	0	4.5	22.7	7.2	5.6	28.0
Chiang-si-wan						0			14.1		54.1	27.6	12.6	47.1
Nan-Chang-wan	3.5	74.8				7.4	26.4	71.9	6.7	8.7	34.6	6.2	8.2	43.3
Lu-kwa-peh						2.8	18.2	31.5	2.8	14.7	44.1	5.1	15.4	7.7
Po-yang-tsao	6.5	39.8	2.3	1.2	12.6	10.5	32.7	68.0	3.1	18.5	24.6	6.0	4.8	44.0
China-sien	15.6	5.6				24.2	15.2	63.6				56.8		59.5
Hsu-chow No.34						3.3	0	7.7	10.8	12.7	45.8	5.5	6.3	25.2
South China														
Tung-kuan-yon-nien						7.0	9.3	18.6	16.7	19.4	19.4			
Hsiang-keng	9.2	52.1				0	40.7	18.5	12.5		62.5	3.0	4.5	50.8
Tseng-cheng-hsi-miao						0.7	1.7	11.9	19.6	12.5	60.7			
Chuh-nien-kuh	2.9	31.4	5.4	3.3	16.3	8.0	11.6	64 5	8.5		50.0	13.6	18.6	42.1
Fu-chou	9.9	53.9	11.5	4.1	10 7	10.1	30.3	79.8	12.1	22.7	90.9	4.8	14.3	54.8
Tsao-shan-pei			7.6	1.9	58.5	12.7	9.2	21.4	16.2	8.1	32.4			
O-hou-tsao-chiu	14.0	10.5				5.9	5.1	64.0	6.5	10.4	54.5	6.9		31.0
Kao-shen-kuang												10.4		35.8
O-hou-tsin-tsao						6.1	3.0	18.2	9.1	9.1	100.0			
Lien-chian-mi-tsao-tah	11.3	46.4				16.4	11.5	32.7	11.6	14.5	36.2	13.0	20.4	33.3
Chu-tsao	4.4	9.8				5.1	29.4	73.5	13.0		47.3	2.9	20.6	15.7
Chin tsao	14.8	34.3				9.6	10.4	100.0	5.8		44.2	8.4	8.4	49.4
Ching-pang-nien	4.5	25.0	7.6	4.4	29.4	7.8	20.9	74.8				0.9	13.8	12.1
Kun-min-tsieh-huan	12.0	26.1	9.1	6.7	22.5	6.5	29.5	72.7	11.6		45.3	17.0	25.5	8.5
Tung-yang-tsao						14.0	3.7	100.0	8.6		100.0	3.0		10.4
Hsian-shan-sha-shan						4.9	7.4	70.0	11.1		35 2	17.7		40.6
Sui-nuan-nuo-kuh									1.3		41.9			
Sueh-hua-nien						12.0	8.7	22.8						
Ta-pu-kuen-tzu						16.7	9.5	69.0						
Hai-yan-ta-nian	27.7	71.2							4.3	8.7	17.4			
Fuh-tsiang-tsao-tao									55.6		38.9			
Peh-kuh-mih-miao														
Kan-mi						7.4	5.3	45.7	13.8	5.2	32.8			
Yang-chuen-tao-nian						22 7	12.4	55.7						
Kan-mi(Red beard)						2.6	5.1	50.4	10.3	3.4	29.3			
Tsin-yie-lu-chi-tsao						2.1	4.1	44.6	17.0	8.5	55.3			
						0	0.7	43.2	6.3	10.4	43.8	18.4	13.2	34.2

Tsin-yie-tsao-tao	7.2	8.1							5.4	6.3	24.3
Cheh-ta No.675	9.8	26.2				3.8	7.5	26.4	32.9		43.8
Ning-yan-kang						10.7		37.5	12.5		79.7
I-fung-tsao						9.0	10.3	41.0	12.8		55.8
Peh-mi-nien			2.9	14.7	35.3	3.3	6.7	56.7	7.0	12.7	39.4
Chieh-mi			0	25.0	81.9	10.5	5.3	42.1			
Chan-kuh			5.6	12.6	44.8	10.9		65.2	10.7		94.7
Philippine											
Guinangang						7.4	11.1	59.3			
Ketan kaetoch	5.6	25.9	8.2	7.1	21.2	28.6	16.1	37.5	10.9	28.3	13.0
Macan menita			4.8	15.5	4.8	9.5	23.8	57.1			
Celebes											
Asse Lasse			7.1	6.0	9.5	23.1	7.7	28.6	17.6	23.5	23.5
Asse Tjella			71.4	71.4	100.0						
Padi Banda			6.5	11.7	20.8						
Padi Kasalle	6.9	26.4	9.4	13.7	52.1	3.2		42.9	51.6	27.9	55.9
Padi Ladang	7.4	13.0	0	10.5	49.1	24.4	19.2	32.6			
Padi Palar			5.4	14.3	37.5						
Padi Pentjeng			5.6	2.2	28.9	17.9	20.5	38.5			
Poenoet Hitam			3.1	8.2	13.3						
Padi Sake	2.1	27.1	2.4	3.7	15.9	31.5	15.1	28.8	9.7	12.5	25.8
Semoeran	11.9	2.4	6.7	6.7	38.3	42.9	14.3	78.6	13.6	12.1	47.0
Seratoes Hari									0.9	2.9	20.2
Pintieng			47.4	37.6	15.5	30.8		63.7			
Lesser Sunda											
Baah			0	40.0	40.0						
Boegi Inda			5.8	3.2	36.2				16.7	10.3	46.2
Karike			8.1	9.5	24.3	2.4	12.2	48.8	57.4	17.0	31.9
Ladang			28.2	33.3	56.4	54.5		27.3			
Laka	4.9	9.3	12.3	11.3	34.0	13.9	19.4	80.6			
Djogading Menengah			7.7	11.5	42.3	28.6	21.4	39.3			
Lendak Kesaming			23.1	13.5	14.6	9.9	21.1	16.9			
Manggarai	2.1	37.5	24.6	21.7	53.6	37.5	8.3	87.5			
Montja Naq			7.0	9.9	25.4						

Ronga	3.5	31.8		19.4		72.4	37.8	25.5	87.8	13.4	9 3	71.1
Brondol Poetih				12.5	16.7	47.2						
Neggeang				23.6	7.3	50.9				50.0	66.7	66.7
Soro				12.2	20.3	39.2	35.5	41.9	45.2			
Boera Ropo	31.8	12.7		14.6	10.4	29.2						
Beak ganggas										17.5	19.3	45.6
Beak Salak				19 0	26.6	34.2	68.4	78.9	36.8			
Manggarai							10.3	19.0	53.4			
Montja Mangge				14.2	12.4	90.3				1.9	7.7	55.8
Mentjel				56.3	8.3	45.8	0	50.0	0			
Montja				5.1	3.8	11.5	61.3	53.2	62 8			
Poetih Menok Don No.2				4.4	11.1	20.0	50.0	50.0	100.0	15.8	7.9	34.2
Java												
Padi Boenar	5.8	7.3		2.9		4.3	18.8	28.1	46.9	4.5	18 2	11.4
Padi Seri Mahi	3.1	12.5		5.5	34.5	43.6	16.9	28.2	53.5			
Djambae	12.5	33.3		25.5	23.6	67.3	20.7	27.6	31.0			
French Indo-China												
R. T. S. No.17				12.5	62.5	12.5						
R. T. S. No.24				30.7	66.9	29.1						
R. T. S. No.26				24.0	55.8	65.4						
R. T. S. No.28				23.5	45.6	33.8						
Burma & India												
Anak Mas				23.7	6.2	58.8						
P. T. B. No.16				61.5	53.8	100.0						
Europe & America												
Keau N 525	12.2	16.7										
Bomba	9.5	21.5										
Red Rice (Africa)	15.3	45.8		4.2	50.0	25.0						
Louisiana				4.7	11.5	22.3	4.3		23.9	31.8	0	67.3
Blue Rose	9.8	44.3		15.4	15.4	80.8	3.8		69.8	25.8	12.1	29.3

(D) The fourth experiment (Sowing, Feb. 1; transnlanting, Mar. 26; maturity, July - Sept.). The examination was same as in the former.

(E) The fifth experiment (Sowing, Mar. 31; transplanting, Apr. 31; maturity, Aug. - Oct.). The examination was also same as in (C).

From table 76, the average percentage of infection of each variety-group classified according to the habitats was calculated as table 77, though the number of varieties used for this calculation was considerably different according to the variety-groups and the plant-portions examined as shown in each column of table 76.

So far as the percentage of ear- and node-blast infection is concerned, such a marked difference as evidenced in the leaf-blast resistance was not found between the temperate- and tropical group. In general, however, the percentage of neck-blast infection was lower in many of the variety-groups native to the tropical region than in those to the temperate, though that of the node-blast infection was often opposed to the above. Moreover, it was observed that the actual injury of the different portions of ears as well as nodes is usually slighter in the tropical group than in the temperate. In the temperate group the lesions of those portions are dark in colour bearing abundant conidia and the grains are often sterile as a result of necrosis or disorganizagtion of the tissues of the necks, the rachises, the rachillae or the grains themselves, whereas in the tropical group the lesions are usually lighter in colour with meagre sporulation and the grains are usually fertile, except a small number of varieties.

As regards the contradiction between the conclusions of Sawada *et al.* (*loc. cit.*) in Formosa and Nagai *et al* (*loc. cit.*) in Korea on the neck-blast resistance of the Japanese and Formosan varieties, the nutritional conditions, chiefly nitrogen supply, under which the plants were grown should be considered. As shown in table 77, the percentage of neck-blast infection was distinctly lower in the Formosan group than in the Japanese with nitrogen twice as much as the ordinary amount (*vide* the columns of the bed culture), but under triple nitrogen supply (*vide* the

Table 77. Average percentage of infection of the different portions of ears and the node of culms of the varieties classified according to their habitats.

Habitats	(i) Bel culture					(ii) Paddy field								
	(A) Upland		(B) Flooded			(C) Sown, Jan			(D) Sown, Feb.			(E) Sown, Mar.		
	(a)	(c)	(a)	(b)	(c)	(a)	(d)	(c)	(a)	(b)	(c)	(a)	(b)	(c)
Japan (Lowland)	23 5	25.4	23.7	19.9	33.7	12.2	17.7	33.4	15.1	10.7	50.0	15.9	18.3	31.8
Formosa ("Horai")	11.0	22.1	12.8	6.4	19.1	7.5	12.3	39.2	12.2	10.5	46.4	16.2	19.4	39.2
Japan (Upland)	13.4	19.7	32.8	28.1	52.0	6.9	10.9	29.2	5.3	5.6	42.2	14.3	18.4	54.4
Formosa (mount., upland)	19.9	27.6	23.4	14.2	29.4	12.6	25.7	60.7	17.3	22.6	47.2	8.6	17.3	53.0
Formosa (mount., lowland	14.5	27.2	23.2	17.6	51.9	15.3	35.3	31.7	17.0	20.6	24.2	31.4	20.0	77.1
Formosa (plain)	7.9	16.1	16.7	9.1	38.4	15.3	13.5	38.2	15.3	5.8	67.3	11.6	3.8	72.5
Mongolia & N. China	33.1	31.2	58.1	62.9	80.0	8.7	7.6	70.8	12.0		71.7	7.5	26.6	23.9
Middle China	11.0	36.7	11.9	17.4	31.7	7.6	12.8	58.6	5.6	12.3	51.8	15.4	9.1	38.7
South China	10.6	22.9	8 2	4.1	27.5	7.7	13.2	50.9	12.4	10.0	46.9	10.6	14.4	39.8
Philippine	5.6	25.9				6 5	11.3	13.0	15.2	17.0	51.3	10.9	28.3	13.0
Celebes	7.1	17.2				14.5	16.4	34.6	24.8	15.4	45.1	18.7	15.9	34.5
Lesser Sunda	2.7	22·8				15.7	15.0	41.4	31.5	33.4	52.8	24.7	19.7	50.2
Java	7.1	17.7				11.3	29.1	38.4	18.8	28.0	43.8	4.5	18.2	11.4
Indo-China & India						29.3	48.5	49.9						
Europe, N. America, etc.	11.7	32.1				8.1	25.6	42.7	2.7		46.9	28.8	6.1	48.3

columns of the field culture) the difference of resistance between these two variety-groups was not so distinct and sometimes became adverse. Hence, under the normal nitrogen supply, it is presumed that the Formosan group may be very resistant in comparison with the Japanese. The justness of this presumption was proved by the following experiments which were carried out under normal nitrogen supply.

Table. 78. Comparison of the neck-blast infection of the Horai and Formosan varieties grown under the field condition with normal nitrogen supply in the 1st crop, 1942.

Varieties employad		Percentage of infection	
Group	Name	Neck of ears[1]	Grains[2]
Horai	Taichu Sp. No. 6	35.4	23.8
	Taichu No. 65	36.3	17.2
	Taichu No. 150	13.9	18.7
	Taichu No. 153	10.1	13.8
	Taichu Gl. N. 46	32.2	18.8
Formosan	Uh-rwan-tzu	1.2	11.3
	Peh-mi-fan	3.7	7.9
	I-kung-pao	3.5	5.9
	Pai-ku	2.8	6.1
	U-tsien	3.9	6,0
	Pan-ten-tzu	2.8	6.1
	Chuang-chiang	3.3	4.8
	Sien-lo	6.3	1.5
	Man-tzu	5.2	6.2
	Tsing-kao	4.3	4.9

1) Observation was made on 30 hills for each variety. 2) Ten ears of each first tillers of 10 hills were examined.

Nagai's conclusion, therefore, is quiet agreed with the author's results. In this connection, Sawada *et la* (*loc. cit.*) also reported that, in the 1st crop of 1926 during which season a heavy epidemic occurred, the Formosan varieties were more resistant than the Japanese varieties even under the condition supplied with nitrogen twice as much as the ordinary amount, though they mentioned in the same report that the average percentage of infection during five years from 1921 to 1925 at Taipeh was opposed to the above as already been mentioned. As for the latter phenomenon, they interpreted that, when these two variety-groups were cultured under the similar nutritional condition (normal nitrogen supply),

the necks of the Formosan varieties become more susceptible than those of the Japanese as a result of supernutrition of the former due to less digestive ability of nutriment. This interpretation may perhaps be applied in the case of the excess of nitrogen such as in the author's field experiments (triple N, *vide* table 77), but the contradiction of the above-nemed two series of experiments stated in their report can not be interpreted by this presumption, since the latter experiments, i. e., 5 - years trials from 1921 to 1925, were carried out with the nitrogen of about the half of the former experiment in 1926. Accordingly, the above - named contradiction of their experimental results must be interpreted in other ways, such as, from the view points of disease escaping, the difference of the environmental conditions other than manuring, the difference of the varieties employed, etc.

Section. 2. Anatomical Characters as the Cause of Varietal Resistance

Nagai & Imamura (1930) pointed out that the ratio of the sclerenchyma to the collenchyma of the neck of ears is larger in the Formosan varieties than in the Japanese as well as Korean ones. Comparing the silicification of the epidermal cells of the leaves of the several varieties endemic to Japan and tropical Asia, Tasugi (1943) came to the conclu sion that there is no distinct correlation between the varietal resistance and the above-named, character. As to this problem, the author (1943, b) already reported the results of his studies on the several varieties of the Formosan native rice and of " Horai " type.

The results of this study are summarized and supplemented below.

The resistance of the varieties employed in the present study is shown in the following table.

Table 79. Resistance of the varieties employed in the anatomical study on the varietal resistance.

Resistance of leaves	"Horai"	Formosan
Highly susceptible	Kameno-o	
Susceptible	Taichu Sp.No.6	
Moderately susceptible	Taichu No.65	
Moderately resistant	Taichu No.114, Taichu No.150	Zeng-tou-uh-rwan-tzu
Resistant		Peh-mi-fen, Pai-ku, Sien-lo
Highly resistant		U-tsien

in the first place, these varieties were inoculated after their epidermal layers were injured by scrubing with sand papers in order to confirm whether or not the epidermal layer of the leaves may serve as a barrier for the penetration of the leaves by the fungus under consideration.

Table 80. Results of inoculation conducted on the upper surface of the 4th leaves of 18-day seedlings with or without wound. Experiment No.1.

Varieties employed		Treatment	Length of leaves(cm)	No.of lesions per leaf	Length of lesions(cm)
Type	Name				
"Horai"	Taichu Sp.No.6	Untreated	15.2	2.3	0.4
		Wounded	15.0	5.6	0 5
	Taichu No.65	Untreated	18.5	6.3	0.4
		Wounded	16.9	10.3	0.5
	Taichu No.150	Untreated	17.3	4.7	0.4
		Wounded	16.5	5.7	0.4
Formosan	Zeng-tou-uh-rwan-tzu	Untreated	20.5	1.1	0.5
		Wounded	19.0	1.6	0.4
	Pai-ku	Untreated	15.8	0.5	0.4
		Wounded	17.0	0.6	0.3
	U-tsien	Untreated	14.1	0.3	0.4
		Wounded	15.3	0.1	0.4

Table 81. Results of inoculation conducted on the upper surface of the boot leaf of the adult plants with or without wound. Experiment No.2.

Varieties employed		Treatment	Length of leaves(cm)	No.of lesions per leaf	Length of lesions(cm)
Type	Name				
	Kameno-o	Untreated	29.8	0.5	0 3
		Wounded	27.5	13 5	0.7
"Horai"	Taichu No.65	Untreated	33.0	0.4	0.2
		Wounded	34.5	21.5	0.8
	Taichu No.150	Untreated	39.2	0 9	0.2
		Wounded	40.2	12.9	0.8
Formosan	Zeng-tou-uh-rwan-tzu	Untreated	32.5	0.3	0.2
		Wounded	33.7	5.9	0.9
	Peh-mi-fen	Untreated	32.0	0.2	0.2
		Wounded	34.5	4.4	0.8
	U-tsien	Untreated	28.1	0.5	0.2
		Wounded	30.4	6.3	0.9

Table 82. Results of inoculation with or without wound conducted on the upper surface of the boot leaf of the adult plants of various varieties including those endemic to China and Europe. Experiment No 3.

Varieties employed		Traatment	No.of lesions per leaf	Length of lesions(cm)
Habitat	Name			
Japan	Shinriki	Untreated	0	-
		Wounded	5.20	0.33
Formosa(Horai	Taichu Sp.No.6	Untreated	0	-
		Wounded	12.80	0.42
Formosa(Native)	Peh-mi-fen	Untreated	0	0
		Wounded	8.00	0.56
Formosa(Mount.)	Sabiki	Untreated	0	-
		Wounded	5.02	0.56
Middle China	Chin-sien	Untreated	0	-
		Wounded	0	-
South China	Fu-chow-ta-tsao	Untreated	0	-
		Wounded	0	-
South China	Tung-kuan-yon-nien	Untreated	0	-
		Wounded	0	-
Europe	Blue Rose	Untreated	0	-
		Wounded	5.03	0.30

The above results showed that the leaf epidermal layers may have an important bearing upon the resistance, because the leaves of the above varieties increased their susceptibility when they were inoculated after wounded. These results are perfectly consistent with those noted by Ikata (1931), Shimada (1937), Ito & Shimada (1937), Tochinai & Komiya (1939), etc. In this connection, it is to note that wounding is not always restricted to the outer walls of the epidermal cells, and the protoplasm in the epidermal cells or that of the upper cells of the chlorenchymatous tissues may also be involved to a certain extent. Therefore, it must be born in mind that the wall of the epidermal cells is only a partial requisite for resistance, since the increase of susceptibility due to wounding was higher in "Horai" varieties than in the Formosan as well as Chinese ones, and this fact may denote that the cause of resistance is also involved inside the cells of the epidermis and internal tissues. Setting aside this point, in order to make clear the relation of the anatomical characters of the epidermal layers to the degree of resistance of the both groups of varieties, the width of the outer walls of the motor cells, of the long and accessory cells as well as the length and width of the silicated papillae produced on these cells (fig.21) were measured, since the fungus enters the plant more frequently through these cells (Ito & Hayashi, 1932; Yoshii, 1936; Ito & Shimada, 1937; Kawamura, 1940; Suzuki, 1942). The measurement was restricted to the cells of the upper surface of the leaves in the area between the 2nd large vascular bundles situated in either side of the midrib,since the cells of the underside of the leaves are somewhat resistant than those of the upperside of them (Ito & Shimada, 1937). The figures in the following tables represent the average value of counts made on 50 optical fields for each variety.

21

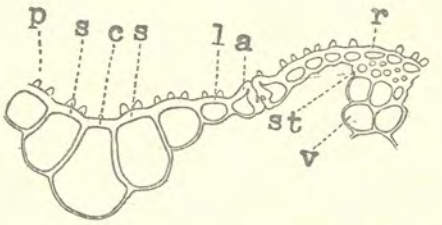


Fig. 21. A diagramatic figure showing the cell-groups of leaf-epidermiexs amined.
c - Central motor cells; s - Side motor cells; l - Long cells; a - Accessory cells ; p - Silicated papillae; l - Long cells not employed for measurement.

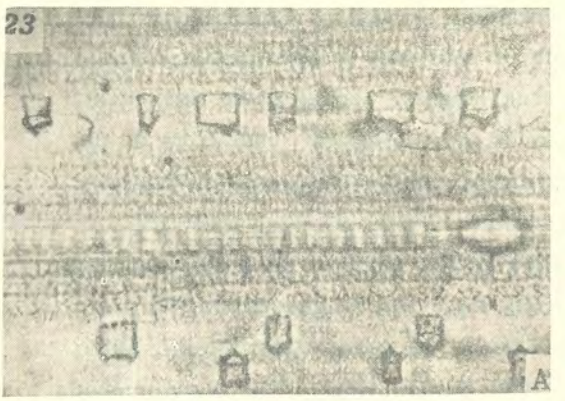
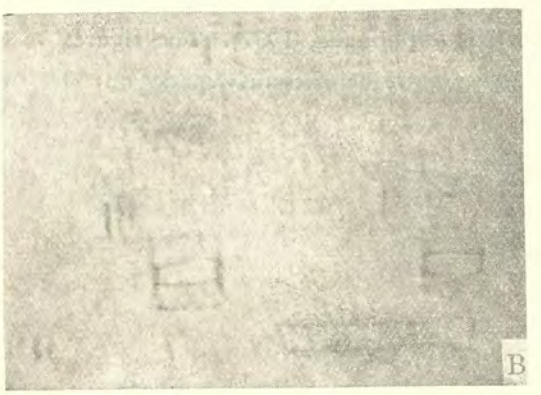


Fig .23. Silicated epidermal cells (The uppermost leaf of 'U-tsien').
A. Silicated motor cells



B silicated motor cells and a long cell.

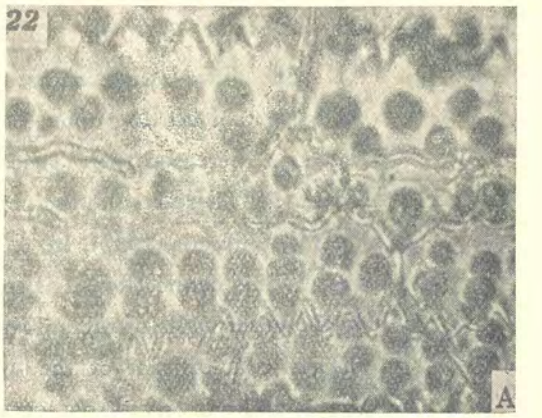
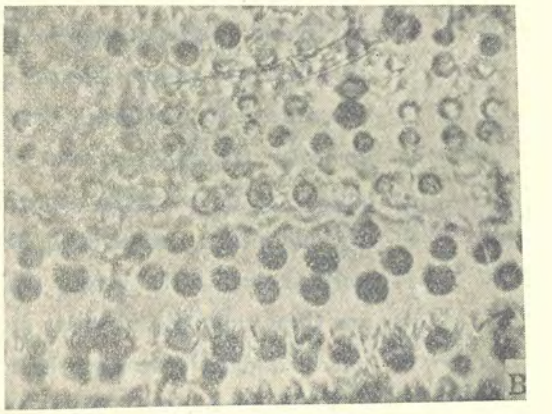


Fig . 22. Epidermal cells and silicated papillae
A. Showing mambrane.



B. Showing silicated papillae

Fig. 24, Pectin reaction of membrane of a central motor cell (The uppermot leaf of 'Us tsien').

Table 83. Thickness of the outerwall and the height and width of the silicated papillae of the epidermal cells of the 4th leaves (from the base) severed from 15-day seedlings grown under the seed-bed condition of the 2nd crop in 1941.

Varicties employed		Cells examined	Thicknoss of wall(u)	Silicated papillac	
Type	Name			Height(u)	width(u)
Horai	Taichu Sp.No.6	Central motor cells	1.16	1.26	8.02
		Side motor cells	1.56	1.92	2.13
		Long cells	1.55	2.36	2.26
		Accessory cells	0.92	—	—
	Taichu No.65	Central motor cells	1.80	1.50	2.00
		Side motor cells	1.55	2.02	2.22
		Long cells	1.54	2.35	2 29
		Accessory cells	1.12	—	—
	Taichu No.114	Central motor cells	1.89	1.84	2 13
		Side motor cells	1.59	2.08	2.23
		Long cells	2.00	2.47	2.62
		Accessory cells	1.00	—	—
Formosan	Zeng-tou-uh rwan-tzu	Central motor cells	1.69	2.10	2.05
		Side motor cells	1.75	2.15	2.31
		Long cells	2.18	2.22	2.42
		Accessory cells	1.05	—	—
	Peh-mi-fen	Central motor cells	2.04	2.02	2.00
		Side motor cells	2.00	2.06	2.09
		Long cells	2.00	2.26	2.46
		Accessory cells	1.14	—	—
	Sien-lo	Central motor cells	1.85	2.08	2.04
		Side motor cells	1.79	2.42	2.18
		Long cells	2.08	2.48	2.46
		Accessory cells	1.08	—	—
	U-tsien	Central motor cells	2.14	2.23	2.32
		Side motor cells	2.00	2.40	2.77
		Long cells	2.13	2.51	3.03
		Accessory cells	1.10	—	—

Table 84. Thickness of the outer walls and the height and width of the silicated papillae of the epidermal cells of the boot- and the 2nd (from the top) leaves severed 1 week after blooming from the adult plants grown in the paddy field in the 1st crop, 1941.

Varieties employed		Cells examined	Thickness of outer wall(μ)		Silicated papillae			
					Top 1.(μ)		2nd 1.(μ)	
Type	Name		Top 1.	2nd 1.	Hei't.	Width	Hei't	Width
Horai	Taichu Sp.No.6	Central motor c.	4.64	4,31	2.19	2.71	1.85	2.99
		Side motor c.	3.66	3.70	2.89	5.40	2.33	3.20
		Long c.	3.08	3.05	3.19	3.40	2.33	3.20
		Accessory c.	2.89	2.65	-	-	-	-
	Taichu No.65	Central motor c.	5.36	4.80	2.16	2.83	1.76	2.89
		Side motor c.	4.04	4.37	2.77	3.00	2.29	3.17
		Long c.	3.54	3.54	3.08	2.90	3.12	3.42
		Accessory c.	2.99	3.00	-	-	-	-
	Taichu No.114	Central motor c	5.04	5.67	2.16	2.88	2.56	3.00
		Side motor c.	4.59	4.31	3.17	2.92	2.38	3.00
		Long c.	3.77	3.62	3.34	3.23	2.69	2.88
		Accessory c.	3.18	2.79	-	-	-	-
Formosan	Zeng-tou-uh-rwan-tzu	Central motor c.	5.47	6.19	2.93	3.20	3.01	3.56
		Side motor c.	4,08	5.16	3.08	3.95	3.49	3.76
		Long c.	3.85	4.16	3.39	4.31	4.76	3.88
		Accessory c.	3.69	3.65	-	-	-	-
	Peh-mi-fen	Central motor c.	5.36	5.73	2.84	3.25	2.77	3.30
		Side motor c.	4.31	4.44	3.39	3.90	3.54	3.70
		Long c.	3.85	4.05	3.85	3.89	3.67	3.89
		Accessory c.	3.08	3.45	-	-	-	-
	Pai-ku	Central motor c.	6.87	6.31	2.68	3.19	3 34	3.25
		Side motor c.	4.77	4.87	3.85	3.90	3.54	3.80
		Long c.	4.12	3.87	3.85	3.89	3.82	3.99
		Accessory c.	2.77	3.39	-	-	-	-
	U-tsien	Central motor c.	6.16	6.00	2.74	3 25	3.45	3.80
		Side motor c.	4.62	4.87	3.54	3.95	4.08	4.05
		Long c.	4.00	4.54	3.56	3.99	4.16	4.11
		Accessory c.	3.19	3.34	-	-	-	-

As shown in the above two tables, regardless of the age of plants, the thickness of the outer walls of the epidermal cells is greater in the Formosan varieties than in the "Horai" ones, though it is not always parallel with varietal resistance. The similar phenomenon has already been observed by Suzuki (1937) who worked with the resistant and susceptible varieties native to Japan. It seems likely, therefore, that the thickness of the outer walls of the epidermal cells is useful for preventing the fungus from invading the host. Furthermore, the same materials

were also tested microchemically.

(1) Cutin. Although this substance is present on the surface of the motor cells to a certain extent, the quantitative difference within the varieties tested has been hardly recognizable.

(2) Cellulose. The reaction of this substance is very remarkable in the outer walls of the motor cells and less in the accessory cells, though little or no reaction has been observed in those of any other cells. Therefore, in order to confirm the relation of the grade of cellulose reaction to the varietal resistance, test was made on 100 optical fields for each variety, since according to Ito & Hayashi (1932), Ito & Shimada (1937) and Yoshii (1936), infection occurs mostly at the motor cells, less frequently at the accessory cells and rarely at the long cells and others. The results of this examination showed that the "Horai" varieties, Taichu Sp.No.6 and Taichu No.65, were not only larger in number of the cells stained with chloriodide of zinc, but also deeper in colour than the Formosan varieties, though one "Horai" variety, Taichu No.150, showed a close resembrance to the Formosan group.

(3) Pectin. The reaction of pectin (fig.24) by ruthenium red was similar to that of cellulose. In consideration of the fact that the fungus has an ability to decompose "cellulose" (Satoh, 1931; Seto, 1936; Inoue, 1939; Hemmi, 1941) and pectin (Yoshii, 1936), the above-mentioned reactions of celluiose and pectin appear to have some relation to the invasion of the blast fungus.

(4)Silica. The number of the silicated epidermal cells of the leaves was counted on 200 optical fields of Winkel 5 x 3a for each variety.

Table 85. Number of the silicated epidermal cells of the leaves of "Horai" and Formosan varieties per one optical field of Winkel 5 x 3a.

Varieties employed		Cells examined	Materials employed※		
Type	Name		A	B	C
Horai	Taichu Sp.No.6	Motor cells	2.91	3.10	3.30
		Long cells	0.01	0.25	0.18
		Short cells	0	0.08	0.02
		Accessory cells	0	0	0
	Taichu No.65	Motor cells	3.98	1.76	6.11
		Long cells	0.01	0.05	0.10
		Short cells	0	0.01	0.04
		Accessory cells	0	0	0
	Taichu No.150 (A & B)※ Taichu No.114 (C)※	Motor cells	2.76	2.12	5.77
		Long cells	0.04	0.06	0.09
		Short cells	0	0.02	0.01
		Accessory cells	0	0	0.01
Formosan	Zeng-tou-uh-rwan-tzu	Motor cells	1.46	1.59	7.46
		Long cells	0.01	0.07	0.07
		Short cells	0	0.01	0.02
		Accessory cells	0	0	0
	Peh-mi-fen	Motor cells	4.10	2.59	7.88
		Long cells	0.02	0.13	0.39
		Short cells	0	0.06	0.03
		Accessory cells	0	0	0
	Sien-lo (A & B)※ Pai-ku (C)※	Motor cells	6.20	4.96	4.97
		Long cells	0.07	0.20	0.10
		Short cells	0	0	0.01
		Accessory cells	0	0	0
	U-tsien	Motor cells	6.21	3.90	6.65
		Long cells	0.18	0.66	0.25
		Short cells	0	0.02	0.10
		Accessory cells	0	0	0.01

※ Materials employed

A. The middle part of the 4th leaves (from the base) of the seedlings grown under the glass house condition.

B. The middle part of the 4th leaves (from the base) grown under the seed-bed condition of the 2nd crop.

C. The middle part of the boot leaves of the adult plants grown under the field condition.

It was shown by the above table that the correlation between the number of the silicated cells and the varietal resistance is rather indis-

tinct, though the Formosan group has a tendency to have more silicated cells than the "Horai" varieties. Several authors, such as Suzuki (1937, *et passim*), Akimoto (1939), Baba (1944), etc., hold that the silicification of the epidermal cells is correlated to a certain extent with the varietal resistance. As just shown above, however, the author's results were not in so close agreement with those of the above-named, and was rather in harmony with the data given by Tasugi (*loc. cit.*). Judging from the results of the present experiments, it is concluded that the anatomical characters as well as the microchemical natures of the epidermal layers of the leaves may take part in the resistance-susceptibility relation between "Horai" and Formosan varieties to some extents. It goes without saying, however, that in order to solve this matter decidedly, other physiological and protoplasmical characters also should be taken into consideration.

Section 3. Chemical Characters as the Cause of Varietal Resistance

Comparisons of the content of certain chemicals in the varieries native to the different latitudinal regions were carried out by use of microchemical and macro-analytical methods for the purpose of clarifying the meaning of those substances upon the varietal resistance. The first examination was undertaken on the content of silica by means of the microchemical method with the useo f the middle part of the fourth leaves (from the base) of 30-day seedlings grown under the glass house condition. As will be seen in the following table, the results of the present examination was in accord with those of the foregoing section.

Table 86. Number of the silicated epidermal cells per unit area (an optical field of Winkel 5 x 7a) at the middle of the fourth leaves (from the base) of the 30-day seedlings of the temperate and tropical varieties

Varieties employed		Grade of resistance		No. of silicated cells			
Name	Habitat	No. of lesions per plant	Length of lesions (cm)	Motor cells	Long cells	Short cells	Accessory cells
Shinriki	Japan	6.7	0.80	1.50	0.07	0	0
Taichu No 65	Formosa(H)	4.1	0.44	2.08	0.08	0	0
Taichu No.150	Formosa(H)	2.8	0.30	2.00	0.02	0.01	0
Huen-shui-tao	Mongolia	3.8	0.14	3.05	0.04	0	0
Hu-lo-tao	N. China	4.7	0.20	0.87	0.01	0	0
Chian-si-ban	M. China	2.8	0.08	3.06	0.01	0	0
Blue Rose	Europe	0.8	0.25	2.01	0.02	0	0
Louisiana	N. America	0.1	0.01	4.01	0.06	0	0
U-tsien	Formosa(N)	0	—	4.78	0.05	0.01	0
Sien-lo	Formosa(N)	0	—	1.07	0.02	0	0
Fu-cho-ta-tsao	S. China	0	—	3.01	0.05	0.01	0
Chan-kuh	Hainan	0.3	0.01	2.07	0.04	0.02	0
Lua Soi	Fr. Indo-Ch.	Trace	—	3.05	0.02	0.01	0
Pin Keow	Siam	Trace	—	4.00	0.06	0	0
Emata	Burma	Trace	—	5.01	0.01	0.01	0
Pacchai Perunel	India	1.2	0.02	3.05	0.02	0	0
Gurdoi	India	Trace	—	1.05	0.08	0	0
Apostol	Philippine	0	—	4.00	0.02	0	0
Surjamkhi	India	0	—	4.08	0.10	0.02	0
Seri Mahi	Java	0	—	3.64	0.07	0	0

In this connection, Kobo & Kimura (1942) pointed out from their manuring experiment that the ratio of silica to ash content in the varieties endemic to tropical Asia is less than 55, whereas in the case of the varieties endemic to Japan and North America it was about 50. From these facts, it is concluded that the silicification of the epidermal cells may not be so important as a factor of varietal resistance as advocated by some workers.

In the next place, total nitrogen content in the leaves of the temperate and tropical varieties was determined with the use of the plants at the tillering stage, which were cultured carefully side by side in the paddy field of the lst- and the 2nd crop in 1943.

Table 87. Content of total nitrogen in the leaves of the plants at rhe tillering stage of the varieties native to the temperate and tropical regions.

Varieties employed		Grade of infect. at the lst crop	Total N (%, Dry basis)	
Name	Habitat		lst crop	2nd crop
Toyokuni	Japan	++++++	5.12	5.03
Shinriki	Do.	++++++	5.20	5.05
Sakata-wase	Do.	+++	4.95	4.75
Kameji	Do.	++++	4.64	4.95
Hatsuhikari	Do.	++++++	5.16	5.08
Norin No.1	Do.	++++	4.86	4.84
Kameno-o No.1	Do.	++++	4.51	4.21
Kyushu No.58	Do.	++++	4.65	5.03
Taino No.47	Formosa(H)	++++	4.86	4.60
Taihoku No.7	Do.	+++	4.45	5.05
Taichu Sp.No 6	Do.	++++++	4.90	4.09
Taichu No.65	Do.	++++	5.18	4.80
Taaichu No.150	Do.	+++	4.96	5·08
Tichu N-.153	Do.	+++	4.86	5.29
Taichu Cl.No.46	Do.	++++++	5.12	4.73
Taitung-tsai-lai	Mongolia	++	4.36	3.64
Huen-shui-tao	Do.	++	4.75	4.05
Hu-lo-tao	N.China	+++	4.70	4.09
Lu-kwa-peh	M.China	+++	4.88	4.99
Hsu-chow No.34	Do.	+++	4.86	4.90
Blue Rase	Europe	++	4.49	4.69
Chien-sien	M.China	—	3.46	4.94
Chian-si-ban	Do.	±	4.21	5.03
U-tsien	Formosa(N)	—	4.51	5.29
Peh-mi-fen	Do.	—	4.15	5,21
Sien-lo	Do	—	4.17	4.86
Fu-cho-ta-tsao	S.China	—	4.47	4.82
Kun-min-tsieh-huan	Do.	—	4.47	4.68
Tung-kuan-mau-tzu	Do.	—	4.17	4.69
Peh-mi-nian	Hainan	—	3.96	4.86
Chan- kuh	Do.	±	3.78	4.60
Lua Soi	Fr.Indo-China	—	3.89	4.62
Mon Nhat	Do.	—	4.19	4.73
Pin Keow	Siam	—	4.10	4.90
Poung Ngeun	Do.	—	4.60	5.06
Emata	Burma	—	3.86	4.01
Heenati	India	—	4.12	4.86
Sudumawi	Do.	—	3.90	4.59
Surjamukhi	Do.	—	4.54	5.00
Anak Mas	Malay	—	3.98	4.96
Apostol	Philippine	—	4.16	5.04
Cariniosa	Do.	—	3.71	4 01
Bogo	Celebes	—	4.06	3.96
Seri Mahi	Java	—	3.85	4.30
Ladang	Lesser Sunda	—	3.79	4.23

(H) — 'Horai' varieties, (N) — Native varieties.

The results of the above experiment, especially those of the 2nd crop, were not clear-cut, though many of the temperate varieties proved

to contain nitrogen more abundantly than those of the tropical ones. As regards the nitrogen metabolism of the different variety-groups, *i.e.*, *"japonica" and "indica"*, Wada (1942) pointed out that, under the Japanese conditions, the amount as well as rapidity of nitrogen absorption are larger in the latter than in the former accordingly, when they are similarly manured, the latter becomes more luxuriant and slender and is affected more easily by the rice-borer, chilo simplex Butler, whereas the former is opposed to the latter in the growth as well as the resistance to the insect.※ As has already been stated, the interpretation of Sawada *et al.* (1927) on the neck-blast resistance of the Japanese and Formosan varieties in relation to the nutritional conditions is almost the same as that of the above-named. So far as the author's present experiments are concerned, however, it must be born in mind that less content ef nitrogen in some temperate varieties and higher content of it in some tropical ones at the time of examination is due greatly to the plant-ages. This phenomenon, can be interpreted chiefly by the fact that the former, especially the varieties endemic to the higher latitudinal regions, are sensitive to short day, hence, they are rather fast to reach the booting stage on account of the promotion of reproductive growth, while the latter are still at the culmination of tillering (*vide* chapt.V). The fact that the results of the 2nd crop was rather indefinite might be due to the effect of short day (accordingly the age of plants) and also to that of warmness *vide* chapt.IV). Therefore, it is advisable that the quantitative analysis of the nitrogen compounds in the leaves should be repeated again at the early tillering stage, since up to that stage the nitrogen metabolism of the leaves may be least effected by photoperiod. The seedlings employed in the presant experiment were cultured under the glass-house condition in the months of April to May, 1945, during which season the weather was rather cool and the day length was fairly long.

※ According to the author's experiments in Formosa on another rice-borer, Schoenobius incertellus Walker, the resistance-susceptibility relation of those two different variety-groups is rather contrary to the above (Hashioka, not published).

Table 88. The amount of nitrogenous compounds in the leaves of the temperate and tropical varieties at the early tillering stage (%,dry basis).

Varieties employed		No. of	Total	Protein-	Non-prote-	Soluble
Name	Hebitat	lesions	N	out N	inous N	N
Shinrik	Japan	5.8	4.21	3.76	0.45	0.39
Kameji	Japan	5.8	3.90	3.51	0.39	0.35
Taichu No, 65	Formosa (H)	4.6	3.85	3.47	0.38	0.33
Taichu No. 150	Formosa (H)	3.0	3.96	3.60	0.36	0.30
Taichu Gl. No. 46	Formosa (H)	6.1	4.16	3.61	0.55	0.34
Hu-lo-tao	N. China	2.1	3.46	3.04	0.42	0.35
Blue Rose	Europe	1.4	4.05	3.68	0.37	0.29
Chin-sien	M.China	0	3.48	3.11	0.37	0.32
Pai-ku	Formosa (N)	0	3.59	3.19	0.41	0.32
Peh-mi-nien	Hainan	0.1	3.68	3.34	0.34	0.30
Heenati	India	0	3.60	3.28	0.32	0.20
Guinangang	Philippine	0	3.41	3.18	0.25	0.15
Seri Mahi	Java	0	3.67	3.28	0.40	0.35
Bali	Lesser Sunda	0	3.51	3.18	0.33	0.24

As seen in the above table, the amount of total nitrogen and proteinous nitrogen is larger in the temperate varieties than in the tropical ones, though these figures are not always parallel with the varietal susceptibility. A somewhat similar tendency has also been noticed in the case of soluble nitrogen.

In the next place, potash content in the above-named plants was examined.

Table 89. Content of potash in the leaves of the plants at the early stage of tillering in the temperate and tropical varieties (%,day basis).

Varieties employed		Potash
Name	Habitat	
Shinriki	Japan	2.70
Taichu No. 65	Formosa (Horai)	2.75
Taichu No. 150	Formosa (Horai)	2.45
Hu-lo-tao	North China	2.86
Hsu-chow No. 34	Middle China	2.10
Blue Rose	Europe	2.44
U-tsien	Formosa(Native)	2.45
Chin-sien	Middle China	2.40
Fu-cho-ta-tsao	South China	2.66
Emata	Burma	2.45
Guinangang	Philippine	2 20
Seri Mahi	Java	1.89
Ladang	Lesser Sunda	2.24

The results of this experiment showed that potash content has almost no definite relation to variatal resistance, though it is somewhat higher in the temperate varieties than in the tropical ones.

Considering the results stated above, the following conclusion may be induced. The degree of silicification of the leaf epidermal layer is of minor importence as a factor of varietal resistance, though, as has been stated in this paper, it has an important bearing on resistance when susceptible varieties are grown under different environmental conditions. Although the content of total nitrogen and proteinous nitrogen showed a considerable correlation to varietal resistance, it can not be considered to be a chief cause of difference of resistance between the temperate and tropical varieties. It must be admitted, however, that these differences may have some relation to resistance, when a comparison is made only between the Japanese lowland varieties. In this connection, it is also to note that, according to Baba (1944), the amount of ammoniacal and soluble nitrogen in the leaves of several Japanese lowland varieties is in positive correlation to the varietal susceptibility, but the results of the present investigation is inconsistent even with this finding. In order to iuterpret this problem more conclusively, further studies should be carried out, inasmuch as the above two studies were not only different in the varieties employed but also insufficient in the number of varieties used. As has already been stated, the content of potash showed a rather negative correlation to the varietal resistance, though Suzuki (1944) advocated that certain Formosan varieties contain more potash than the Japanese ones. The conclusion of the latter, however, may leave some room for further consideration, since this concept was induced merely from the microchemical determination conducted with a limited number of varieties. In connection with the chemical aspect of the blast resistance, there is certain basic studies on the cause of increase of leaf - blast susceptibility of rice plants induced by nitrogen supply. Tahara (1937) concluded that the increase of total nitrogen and the ill - balanced concentration of the different forms of nitrogenous compounds in the leaves, *e. g.*, the extreme increase of non - proteinous nitrogen, causes the susceptibility to

leaf - blast. Ito & Sakamoto (1942) confirmed that soluble nitrogen, especially ammoniacal - and amido - nitrogen, increases in the leaves as a result of nitrogen manuring, though there is no marked change of the content of proteinous nitrogen. It is not obvious whether or not the change of resistance of the same variety induced by the environmental conditions and the difference of the inherent resistance of the different varieties are caused similarly by such chemical changes in the plant bodies as mentioned above. Nevertheless, at present, we incline to the conception that the high resistance of the tropical varieties is due rather to the functional relation than to the nutritional physiology. In this connection, Kawamura & Ono (1944), making cytological studies, proposed a prominent factor governing the resistance of the tropical varieties. According to them, the blast fungus dies soon after the entrance into the epidermal cells of the tropical varieties, probably due to the formation of certain toxic substance in the necrotic host - cells, whereas in those of Japanese varieties the fungus grows well. The senior author of the above - named (1940) also observed the similar phenomenon on the different species of the genus oryza which are very different in their blast resistance. However, as regards the chemical aspect of the above-named phenomenon, it has not yet been clarified, for the reason mentioned above, in order to clarify the cause of varietal resistance, further studies should be made in vitro accompanied by those in vivo.

Section 4. The Change of Varietal Resistance Effected by the Environmental Factors

A. Effect of Temperature

The different varieties native to the different latitudinal regions were grown up to the early stage of tillering under varied air - temperature conditions, *Viz.*, low (15 - 20°C), moderate (20 - 25°C), optimum (25 - 30°C), and high (30 - 33°C), regulated by the same methods mentioned

in chapter IV, section 1, and they were inoculated simultaneously under the same condition. The results of the experiments will be shown in the following three tables.

Table 90. The effect of air temperature on the varietal resistance.

Experiment No.1.

Varieties employed		Growth temp.°C	Height (cm)	No.of leaves	No.of lesions per pl	Lesions (Length x width,cm)	Sporulation
Name	Habitat						
		Low	38.0	4.0	3.63	0.65x0.25	+++
Taichu No.65	Formosa	Opt.	37.5	4.0	1.05	0.50x0.20	+++
	(Horai)	High	45.7	4.0	0.06	0.50x0.20	++
		Low	48.6	5.0	8.26	0,85x0.35	+++
Taichu Sp. No.6	Formosa	Opt.	52.1	5.0	3.24	0.60x0.20	+++
	(Horai)	High	48.6	5.0	2.04	0.65x0.20	++
		Low	47.5	4.5	0.10	0.15x0.07	—
Apostol	Philippine	Opt.	51.8	5.0	0.04	0.10x0.10	—
		High	52.9	5.0	0.16	0.15x0.10	—
		Low	49.8	5.0	0.05	0.07x0.05	—
Macang Pulot	Philippine	Opt.	56.5	5.0	0.04	0.05x0.05	—
		High	52.8	5.0	0.08	0.10x0.06	—
		Low	39.7	4.5	0.04	0.10x0.06	—
Milagrosa	Philipping	Opt.	39.7	4.5	0	—	—
		High	41 2	4.5	0.02	0.20x0.10	—
		Low	44.8	5.5	0.04	0.15x0.08	—
Co.3 (Coimbatore Agr.Expt.Sta.)	India	Opt.	47.5	5.5	0.07	0.15x0.07	—
		High	44.2	5.0	0.05	0.15x0.09	—
		Low	46.7	4.0	0.05	0.20x0.10	—
Hecnati	Ceylon	Opt.	52.5	4.5	0.14	0.20x0.06	—
		High	50.5	4.5	0.10	0.20x0.10	—
		Low	45.8	5.0	0.06	0.20x0.16	—
Pokal Poetih	Bali (Lesser Sunda)	Opt.	54.2	5.0	0.10	0.10x0.00	—
		High	52.0	5.0	0	—	—
		Low	47.8	5.0	0.08	0.20x0.06	—
Gropak Seroeng	Soembawa (Lesser Sunda)	Opt.	47.0	5.0	0.10	0.20x0.15	—
		High	52.0	5.0	0.18	0.30x0.15	—

All the plants were grown for 25 days at each temperature except for those grown at the low temperature, the latter were grown for 29 days. Temperature during growing period: low=9 - 19°C, Opt.=25 - 28°C, high=29 - 32°C.

Table 91. The effect of air temperature on the varietal resistance.

Experiment No.2.

Varieties employed		Growth temp. (°C)	Height (cm)	No. of leaves	No. of lesions per		Lesions (length x width, cm)	Sporulation
Name	Habitat				Plant	1 cm of leaf length		
Shinriki	Japan	Low	39.3	6.2	14.46	0.116	0.48x0.25	+++
		Moder.	53.1	5.8	10.44	0.075	0.50x0.25	++
		Opt.	53.6	5.5	7.16	0.061	0.30x0.25	++
		High	35.8	5.8	6.50	0.067	0.30x0.25	+
Taichu No. 65	Formosa (Horai)	Low	42.5	5.6	10.10	0.084	0.42x0.20	+++
		Moder.	47.0	5.0	5.29	0.047	0.40x0.20	++
		Opt.	47.6	5.3	4.04	0.045	0.40x0.20	++
		High	33.7	5.8	2.50	0.037	0.30x0.12	+
Taihoku No. 7	Formosa (Horai)	Low	47.3	4.0	6.80	0.061	0.35x0.20	++
		Moder.	47.2	4.3	4.50	0.040	0.30x0.10	+
		Opt.	47.6	5.3	4.50	0.036	0.20x0.10	+
		High	34.8	5.5	3.30	0.037	0.20x0.10	+
Kanan No. 2	Formosa (Horai)	Low	43.9	4.3	7.16	0.057	0.50x0.25	++
		Moder.	45.3	4.3	4.67	0.048	0.45x0.20	+
		Opt.	38.6	5.7	4.31	0.045	0.30x0.15	+
		High	38.4	5.3	3.48	0.050	0.30x0.20	+
Chiang-si-ban	Middle China	Low	63.5	4.6	4.88	0.039	0.35x0.20	+
		Moder.	69.1	4.3	2.70	0.018	0.30x0.10	±
		Opt.	66.6	4.7	2.32	0.016	0.30x0.10	±
		High	43.3	4.3	2.65	0.026	0.30x0.10	±
Peh-mi-nian	Hainan	Low	48.0	5.3	1.34	0.012	0.18x0.07	—
		Moder.	49.3	4.7	0.31	0.003	0.15x0.05	—
		Opt.	50.8	5.2	Trace	Trace	—	—
		High	50.1	6.5	Trace	Trace	—	—
Guinan-gang	Philippine	Low	56.8	5.8	2.51	0.021	0.20x0.08	±
		Moder.	57.3	5.4	2.83	0.024	0.10x0.05	±
		Opt.	53.6	6.5	1.48	0.011	0.10x0.05	±
		High	51.0	6.0	0.83	0.007	0.10x0.05	±
Macan Talipina	Philippine	Low	47.0	5.4	3.88	0.032	0.10x0.05	—
		Moder.	47.0	5.3	2.28	0.018	0.10x0.05	—
		Opt.	56.8	5.3	1.42	0.012	0.10x0.05	—
		High	46.5	5.6	3.08	0.025	0.10x0.05	—
Dendah	Soembawa (Lesser Sunda)	Low	46.9	5.2	2.55	0.021	0.10x0.10	—
		Moder.	60.2	5.2	1.64	0.014	0.20x0.10	—
		Opt.	50.6	5.6	1.57	0.013	0.10x0.10	—
		High	49.2	6.0	1.11	0.009	0.10x0.10	—

All the plants were grown for 25 days. Temperature during growing period:

Low=16 -27°C; moderate=24 - 27°C; optimum=27 - 29°C; high=29 - 33°C.

Table 92. The effect of air temperature on the varietal resistance.

Experiment No.3.

Varieties employed		Growth temp. (C°)	Height (cm)	No. of leaves	No. of lesions per		Lesions (Length x width cm)	Sporulation
Name	Habitat				Plant	1cm of leaf length		
Riku-u No.132	Japan	Low	44.2	8.2	11.2	0.105	1.60x0.65	+++
		Opt.	49.0	7.7	11.1	0.088	1.10x0.40	++
		High	47.2	7.3	2.1	0.018	0.70x0.18	+
Shinriki	Japan	Low	41.1	7.4	10.5	0.104	1.25x0.45	+++
		Opt.	51.0	7.4	11.0	0.087	0.85x0.40	++
		High	42.2	6 4	5.9	0.055	0.80x0.20	+
Taiboku No.7	Formosa (Horai)	Low	47.2	6.2	6.2	0.089	1.20x0.25	+++
		Opt.	57.4	5.8	3.3	0.057	0.90x0.04	+++
		High	42.4	5.4	2.0	0.023	0.90x0.20	+
Taichu No.65	Formosa (Horai)	Low	40.2	7.3	7.5	0.091	1.30x0.40	+++
		Opt.	53.9	5.7	6.6	0.058	1.10x0.40	++
		High	38.9	5.0	1.2	0.015	0.80x0.20	+
Kanan No.2	Formosa (Horai)	Low	42.2	7.0	4.5	0.052	1.00x0.35	+++
		Opt.	50.9	6.6	2.6	0.028	0.70x0.35	+
		High	42.0	6.4	2.0	0.022	0.80x0.25	+
Chiang-si-wan	Middle China	Low	57.0	7.4	7.6	0.070	0.30x0.15	+
		Opt.	65.4	6 4	5.8	0.038	0.20x0.10	±
		High	63.4	6.0	4.4	0.038	0.20x0.15	−
Tung-huan-yon-nine	South China	Low	51.2	9.0	5.8	0.048	0.30x0.10	−
		Opt.	65.8	5.3	5.1	0.051	0.20x0.15	−
		High	57.2	4.3	3.8	0.038	0.20x0.15	−
Chan-kuh	Hainan	Low	66.4	9.0	2.2	0.015	0.35x0.20	±
		Opt.	72.0	6.7	1.9	0.013	0.30x0.20	−
		High	82.5	5.7	0.4	0.003	0.20x0.20	−
Unknown	India	Low	55.5	6.8	4.2	0.036	0.50x0.15	−
		Opt.	72.8	7.2	5.1	0.034	0.50x0.20	−
		High	65.8	5.2	0.2	0.001	0.30x0.15	−
Blue Rose	Europe	Low	45.0	4.7	2.6	0.034	1.30x0.15	+
		Opt.	66.7	5.0	2.5	0.026	0.70x0.12	±
		High	43.3	4.0	0.3	0.003	0.25x0.10	±

All the plants were grown for 25 days. Temperature during growing period: Low=12 - 26°C; optomum=27 - 29°C; high=31 - 33°C.

As already stated in chapter IV, in most of the varieties tested, resistance is enhanced in proportion to the increase of temperature at which the plants are grown, but the change of resistance at various temperatures is more distinct in the temperate varieties than in the tropilca ones.

Furthermore, as seen in the following table, the total nitrogen content of the leaves is higher in the temperate varieties than in the tropical, and the rate of decrease of nitrogen at higher temperatures is more conspicuous in the former than in the latter showing a considerable agreement with the grade of infection, so far as the present experiments are concerned.

Table 93. The total nitrogen content (dry basis) and the leaf colour of the seedling of the temperate and tropical varieties grown at different air temperatures.※

Varieties employed		Low		Optimum		High	
Name	Habitat	N(%)	Colour	N(%)	Colour	N(%)	Colour
Riku-u No.132	Japan	4.99	++	2.93	+	2.32	±
Shinriki	Japan	4.23	+++	4.06	++	3.28	+
Taichu No.65	Formosa (Horai)	4.19	+++	4.06	++	2.24	±
Kanan No.2	Formosa (Horai)	4.75	+++++	4.23	+++	3.71	++
Chiang-si-wan	Middle China	3.78	++	3.63	+	2.15	—
Chan-kuh	Hainan	3.71	++	3.19	+	3.09	±
Unknown	India	3.23	+	3.19	+	3.40	±
Blue Rose	Europe	4.25	++	4.06	+	2.28	±

※ Namber of (+) marks represents the depth of leaf colour.

From the results mentioned above, the distinct difference of resistance revealed by the temperate and tropical varieties under the different temperature conditions seems to be due to the inherent character of these two groups pertaining to nitrogen content and leaf colour. In this connection, however, it is to be remembered that the varietal difference of sensibility to temperature is in intimate relation to nitrogen content. As stated in chapter IV, the nitrogen content of the rice plants decreases in the warm weather or under the condition of short day owing to a promotion of their reproductive growth.

In the next place, it is worthy of special notice that the varieties endemic to the regions at the lower latitudes, such as those from Ceylon(ca. 10°N) and Lesser Sunda (ca. 9°S), are rather resistant when they are grown at the low temperature, so far as the results of the present experiments are concerned. This fact seems to be due to the difference of temperature requirement for growth between the temperate and tropical

varieties. At the extreme low temperature (below ca. 10°C) the rice seedlings have a tendency to become yellowish and resistant on account of lower concentration of nitrogen, but these phenomena are noticed more distinctly in the tropical varieties than in the temperate. The above mentioned relations between the varietal resistance and temperature condition under which the plants are grown are considered to be chiefly due to the nitrogen metabolism, the degree of which can be read by the tone of leaf colour. The leaf colour of the varieties of the both types under different air temperatures are shown as follows:

Table 94. Showing the leaf colour of the temperate and tropical varieties at different air temperatures.

Variety group	Growth & colour	Temperature for growth (°C)						
		<10	10-15	15-20	20-25	25-30	30-35	35<
Temperate	Growth	Extreme low	Low	Rather low	Moderate	Optimum	High	Extreme high
	Leaf colour	Pale green	Dark green	Deep green	Green	Green	Pale green	Wither
Tropical	Growth	Extreme low	Very low	Low	Moderate low	Optimum	High	Extreme high
	Leaf colour	Wither	Yellowish green	Pale green	Green	Pale green	Yellowish green	Wither

The above relation is also seen in the field, especially in the seed-bed of the lst crop in the northern half of Formosa, since the temperature during this season is 14 - 17. 5°C which is corresponded to the low or moderately - low temperature for the temperate type and to the extreme low or low for the tropical.

Table 95. The leaf colour of the varieties native to the different latitudinal regions under the seed - bed condition of the Ist crop. ※

Habitats of varieties (Types)	No. of varieties employed	Tone of leaf colour
Japan (Lowland)	29	5.37
Formosa ("Horai")	25	5.34
Japan (Upland)	31	4.00
Formosa (Mountain)	58	3.93
Formosa (Plain)	20	2.95
Middle & South China	90	2.07
Tropical Asia	32	2.01

This examination was carried out on the seed - bed of the Ist crop in 1943 (17.6°C in aver.) at Taichung. Tone of leaf colour is determined by the average value of the index numbers representing six different colour effects from yellowish green (index no.1) to dark green (index no.6), as observed with the naked eye.

※ A somewhat similar phenomenon was already reported by Suzuta (1929) and Ohkura et al. (1942).

In view of the experiments of Mitsui (1940) who confirmed that the chlorophyll content in the leaves of rice plants increases in parallel with supply of ammonium sulphate, the above mentioned relations seem to be chiefly due to the nitrogen metabolism of the plants. In this respect, the nitrogen metabolism of the rice plants which is represented by leaf colour is thought to interdependent on the temperature conditions under which they are grown, as shown below.

(1) At the extreme low temperature, the plants become resistant, a light leaf colour and a small amount of nitrogen in the tissues due to the feeble photosynthetic activity and nitrogen absorption.

(2) At the low temperature, the plants become most susceptible and darkest in leaf colour due to excees of nitrogen content per unit volume as a result of the lesser photosynthetic activity in comparison with nitrogen absorption as well as of an enfeebled plant growth.

(3) At the moderate temperature, the plants become rather resistant and normal in leaf colour, since the amount of nitrogen absorbed by roots and that of carbohydrate produced in the leaves are well balanced.

(4) At the optimum temperature, the plants become resistant and

light in leaf colour by the reason that the amount of nitrogen per unit volume of the plant bodies is small because of the rapid growth due to greater photosynthesis.

(5) At the high temperature, the plants are very resistant and light in leaf colour owing to the depression of nitrogen absorption and photosynthesis.

Basing on this assumption, the above - mentioned fact that certain varieties endemic to the lower latitudinal regions showed resistance at the cold conditions may be explained as follows:

The condition which induced the above - mentioned phenomenon may be comparable to the extreme low temperature for the tropical varieties, consequently, under this temperature - condition these varieties are unable to grow normally, though the temperate ones can grow well and are most susceptible.

From the results stated above, it is inferred that the temperate varieties are sensitive to temperature under which they grow and their susceptibility which is greatly effected by it may be due to their inherent character, while the tropical varieties are quite opposite to the former, and that such relations between the varietal resistance and the temperature at which they are raised are in intimate correlations with the nitrogen metabolism as represented by leaf colour.

B. Effect of Manuring

Several varieties native to the different latitudinal regions were cultured in porcelain pots (1/200,000 ha. in area) with different amount of nitrogen and inoculated at the later stage of tillering in order to confirm the change of their resistance due to the amount of nitrogen given. These experiments were conducted in the wire - gauze house during the course of the lst crop of 1946. The resultant data are shown in table 96.

As shown in table 96, the temperate varieties distinctly increased their susceptibility in proportion to the amount of nitrogen, whereas in the tropical ones such a phenomenon was hardly recognizable, more - over, some of the latter remained uninfected even in the plots received the excess of nitrogen.

Table 96. Results of the inoculation on the different varieties endemic to the temperate and tropical regions grown under different conditions of nitrogen supply up to the tillering stage.

Varieties (Habitat)	Nitrogen Supply	Growth			Grade of infection				
		Height (Cm)	No. of tillers	Leaf colour	No. of lesions	Shape of lesions ※	Colour of lesions	Lesions (Leng.x Width,cm)	Sporulation
	None	47.5	4.2	+	0.25	A	Brown	0.2x0.1	—
Shinriki	Half	59.7	7.0	++	1.75	B	Brown	0.7x0.1	±
(Japan)	Normal※※	67.0	10.1	++++	1.25	A	Brown	0.4x0.2	+
	Twice	70.3	17.7	++++++	16.00	A	Dark Brown	1.0x0.2	+++
	Quadruple	55.4	15.3	++++++	29.50	A	Dark grey	1.0x0.2	+++
	None	52.2	5.5	+	0	—	—	—	—
Taichu No.	Half	60.2	10.3	+++	1.25	B	Brown	0.7x0.1	±
65(Formosa,	Normal	68.3	11.8	+++++	3.00	B	Brown	1.1x0.2	+
"Horai")	Twice	70.2	18.8	++++++	17.75	A	Dark grey	1.2x0.2	+++
	Quadruple	60.2	15.0	++++++	34.90	A—B	Dark grey	1.1x0.2	+++
	None	49.5	1.5	+	0	—	—	—	—
Blue Rose	Half	70.3	6.5	++++	1.00	B—C	Pale brown	0.6x0.1	±
(Europe)	Normal	74.7	7.3	+++++	0.50	A—B	Pale brown	1.4x0.1	+
	Twice	72.0	8.0	+++++	1.15	A—B	Pale brown	1.0x0.2	+
	Quadruple	60.0	8.3	++++++	7.53	A—B	Brown	0.9x2.0	+
	None	60.0	3.3	+	0	—	—	—	—
Tobura	Half	80.3	5.5	+++	0.75	B	Orange brown	0.6x0.1	±
(Formosa,	Normal	80.0	6.0	++++	0.01	B	Orange brown	0.5x0.1	—
mount.)	Twice	85.5	6.5	++++	0.50	B	Orange brown	0.1x0.1	—
	Quadruple	80.2	5.3	++++	1.50	B	Orange brown	0.8x0.1	±
	None	56.8	3.8	+	0	—	—	—	—
Pacchai	Half	70.2	7.0	++	0	—	—	—	—
Perunel	Normal	72.5	10.0	++++	0	—	—	—	—
(India)	Twice	73.5	13.5	++++	0	—	—	—	—
	Quadruple	63.9	13.8	++++	0	—	—	—	—
	None	51.5	2.8	+	0	—	—	—	—
Plaiuk kai	Half	68.8	9.3	+	0	—	—	—	—
(Siam)	Normal	67.0	10.3	++	0	—	—	—	—
	Twice	64.0	10.0	+++	0	—	—	—	—
	Quadruple	60.5	9.5	+++	0	—	—	—	—

※A type - Typical fusiform lesions, B-Small ellipse or fusiform lesions, C - Minute ellipse lesions.

※※30 kg. per ha .P_2O_5 and K_2O were given eqully (80 kg. per ha.) in all the plots.

Similar experiments were conducted in the field during the lst crop season in 1947 with the use of 20 varieties endemic to the different latitudinal regions. The plants were cultured with different amount of nitrogen, i. e., non, normal (80 kg. per ha.) and quadruple, phosphorus and potash being given equally (80 kg. per ha.) in all the plots. One plot was 0.1 are in area (180 hills), a single seedling being transplanted (Mar. 25) per hill. Field inoculation was carried out at several times.

Table 97. Results of the field experiments on the effect of nitrogen supply upon the varietal susceptiblity.

Varieties (Habitat)	Nitrogen Supply	Hei - ght (cm)	No. of ears	Blast infect. (%)		Stem - rot infection (%)	Yield (Kg. per ha.)
				Neck of ears	Node of culms		
Shinriki	None	92.7	11.1	0.6		1.7	3,247
(Japan, lowland)	Normal	97.6	12.9	3.7		9.9	4,199
	Quadruple	110.9	16.1	20.4		49.1	1,698
Hatsuhikari	None	75.8	6.4	1.6		0	457
(Japan, lowland)	Normal	84.4	12.7	5.3		16.7	651
	Quadruple	75.5	19.5	14.3		57.2	996
Riku - u No. 132	None	93.5	6.9	1.8		12.9	409
(Japan, lowland)	Normal	101.5	11.6	4.1		7.4	625
	Quadruple	102.0	12.5	6.8		13.4	668
Gaisen	None	93.9	7.2	0	21.5	15.8	2,170
(Japan, upland)	Normal	103.1	10.8	0.4	13.1	25.0	3,349
	Quadruple	114.4	13.3	1.9	100.0	44.0	2,122
Urazo	None	95.6	8.7	5.0	4.2	16.6	3,269
(Japan, upland)	Normal	108.3	9.7	1.8	2.2	0	4,188
	Quadruple	113.7	10.4	6.8	27.8	22.2	2,905
Mino - mochi	None	98.7	7.3	1.5	4.2	21.9	3,317
No. 1 (Japan,	Normal	115.4	9.9	1.7	0.5	22 5	3,798
upland)	Quadruple	119.8	13.0	6.3	15.1	20.5	3,468
Taichu Sp. No. 6	None	102.3	10.0	2.2	2.2	15.0	3,301
(Formosa,	Normal	110.9	11.2	3.1	8.5	11.1	3,903
"Horai")	Quadruple	116.0	12.6	17.3	10.2	58.2	2,241
Taichu No. 150	None	92.1	10.1	0.7	2.8	4.2	3,597
(Formosa,	Normal	102.7	12.9	1.0	9.6	4.0	4,108
"Horai")	Quadrupal	112.2	18.3	5.9	12.6	19.4	2,993
Taichu No. 159	None	104.7	8.1	1.4	3.0	1.4	4,195
(Formosa,	Normal	120.0	8.8	4.0	30.1	5.5	4,841
"Horai")	Quadruple	127.7	12.2	8.1	30.6	16.0	2,743
Taino No. 47	None	94.7	10.0	8.0	6.0	7.5	3,756
(Formosa,	Normal	102.6	14.3	0.9	6.3	4.1	4,266
"Horai")	Quadruple	106.3	16.4	4.6	10.4	36.5	2,993

U - tsien	None	100.8	13.4	0.9	0	2.9	3,486
(Formosa,	Normal	103.8	14.4	0.4	1.0	0	3,486
endemic)	Quadruple	110.3	16.6	0.5	5.8	10.7	3,356
I - kung - pao	None	112.0	10.3	2.2	0	0	3,351
(Formosa,	Normal	123.4	11.3	2.4	9 7	3.3	3,961
endemic)	Quadruple	124.1	13.4	1.7	21.1	32 0	3,194
Ta - mao - tao	None	67.9	3.7	0	0	0	315
(Mongolia)	Normal	73.4	3.6	0	1.2	16.7	274
	Quadruple	71.6	5.2	0	0	8.0	411
Chin - sieng	None	83.3	8.2	0.4		3.2	1,275
(M. China)	Normal	91.4	10.0	0.3		3.6	1,414
	Quadruple	88.6	16.2	0.3		64.3	1,855
Hsu - chow No. 34	None	94.1	12.6	9.4	0.9	2.9	3,709
(M. china)	Normal	115.3	18.6	2.3	4.7	9.4	3,703
	Quadruple	96.1	18.1	9.7	13.4	28.6	2,218
Fu - cho - ta -	None	100.5	9.8	4.9	2.7	2.8	3,814
tsao (S. China)	Normal	115.7	11.0	1.3	5.9	13.5	3,638
	Quadruple	106.7	14.5	0.8	5.2	18.1	2,347
Tsuan - ta - tsao	None	114.6	11.3	0 4	13.5	20.0	3,962
(S. China)	Normal	123.6	13.0	1 2	7.2	0	4,559
	Quadruple	122.0	12.8	6.7	33.3	66.7	1,907
Bomba	None	119.7	5.9	3.3		3.3	2,407
(Europe)	Normal	127.8	8.9	3.8		17.2	3,162
	Quadruple	110.8	10 5	1.1		67.6	1,232
Louisiana	None	101.7	9.1	4.9	7.4	13.9	1,936
(N. America)	Normal	107.1	10.4	10.5	11.3	16 4	2,811
	Guadruple	111.1	10.9	17.9	7.4	100.0	229
Blue Rose	None	117.5	7.7	6.4	7.4	0	2,582
(Europe)	Normal	125.3	8.6	9.5	8.9	1.9	2,688
	Quadruple	107.3	10.5	14.7	13.8	17.5	1,361

As shown in the above table, in many of the varieties tested, the height of plants was larger in the plots of the normal nitrogen supply than in those of the quadruple, but certain varieties, including some tropical and European, were opposed to it. Number of ears increased in proportion to the amount of nitrogen given, but the rate of increase was smaller in the tropical varieties than in the temperate. In general, the neck - and node - blast infection became severer in proportion to nitrogen supply, though this tendency was not distinct in Mongolian, Formosan and Chinese varieties. The infection of stem - rot disease (*Corticium* (*Hypochus*)*Sasakii*) was almost the same as in the blast disease. Yield of the temperate varieties, especially "Horai" which has

been accomodated for the Formosan condition, exceeds that of the tropical varieties in the case of normal manuring, but is quite inferior when the excess of nitrogen is given, while that of the tropical varieties was hardly effected by the surplus of nitrogen. Such a difference is caused chiefly by the change of disease resistance, especially the neck - blast resistance. In order to clarify the above - named relation more definitely, the following experiments was futher carried out in the wire - gauze house during the lst crop season in 1946. Two varieties of "Horai" and Formosan endemic type were cultured in the porcelain pots of 1/200,000 ha. with no -, half -, normal - (80 kg. per ha.) and treble amount of nitrogen, phosphorus and potash being given equally (80 kg. per ha.) in all, except the non - manuring plot. Five pots with 5 seedlings grown together were used for each plot. The chemical constituents of the plants were examined at different ages.

In view of the data as shown in table 98, it is obvious that ash content, of which the most part is presumed to be silica, generally decreases in parallel with the increase of nitrogen given in any of the varieties tested, though not so evident at the tillering and booting stages. Total nitrogen content is contrary to the above. Between the variety - groups, i.e. "Horai" and Formosan, however, we are unable to find any marked difference in centents of these substances to such an extent as to interpret the distinct difference of leaf - blast resistance subsisting between the two. As shown in table 77, in general, the difference of inherent resistance of temperate and tropical varieties to neck - and node - blast, especially the latter, is not quite distinct and it becomes more indistinct with the increase of nitrogen supply, while in the case of leaf - blast the difference is so remarkable that it is not easily effected by the nutritional conditions (*vide* table 96 and 98).

Table 98. Contents of ash and nitrogen in the plant bodies of "Horai" and Formosan varieties of different ages applied with different amount of nitrogen under the 1st crop condition in 1946.

Varieties employed	Nitrogen supply	Infection[1]	Ash content(%, dry basis)					Total N content(%, dry basis)					Leaf colour	
			Seedling (2nd crop)[2]	Tillering	Booting	Maturity		Seedling (2nd crop)[2]	Tillering	Booting	Maturity		Tillering	Booting
						Straw	Grain				Straw	Grain		
Taichu No.65	Non-man.	—	13.00(13.97)	9.11	7.60	13.44	4.47	3.02(2.17)	2.65	0.77	0.69	0.95	++	+++++
	Non N	—	—[3] (13.65)	10.42	10.67	10.72	4.35	2.37(1.65)	2.72	1.26	0.74	1.12	+++	++
	Half N	±	9.42(10.77)	9.08	10.40	11.82	4.52	3.01(2.28)	2.12	0.98	0.74	1.02	++++	+++
	Normal N	+	9.56(13.75)	9.05	11.23	11.12	4.22	4.14(2.30)	2.49	1.23	0.74	1.02	++++++	+++
	Treble N	+++	7.39(14.62)	9.10	10.11	10.40	3.22	4.07(3.72)	3.26	1.30	0.87	1.02	++++++++	+++++
Taichu No.150	Non-man.	—	14.28(14.12)	9.00	9.60	13.71	3.94	2.32(1.80)	3.04	0.98	0.65	1.00	++	+++++
	Non N	—	10.58(15.59)	9.09	9.55	11.85	4.16	2.78(1.85)	2.39	1.23	0.62	1.19	+++	++
	Half N	—	9.12(12.03)	8.79	9.50	11.57	4.59	2.84(3.00)	2.14	1.19	0.62	1.04	+++	+++
	Normal N	+	8.00(13.03)	9.00	10.38	10.25	4.15	3.31(2.50)	2.58	0.91	0.85	1.16	++++++	+++
	Treble N	++	7.30(12.69)	9.08	8.08	10.14	3.54	4.21(3.85)	3.47	1.29	0.74	1.30	++++++++	++++++
U-tsien	Non-man.	—	— (12.64)	9.23	11.20	12.52	4.12	2.28(1.48)	2.56	1.12	0.85	1.30	++	++++
	Non N	—	— (11.68)	9.22	10.15	11.14	4.25	2.68(1.90)	2.20	1.19	0.87	1.09	+	+
	Half N	—	9.84(11.10)	9.07	10.19	11.81	3.96	3.07(1.80)	2.01	1.12	0.74	0.92	+	+
	Normal N	—	10.00(12.52)	9.20	10.16	10.62	3.85	3.37(3.60)	2.09	1.21	0.85	1.15	++++	+
	Treble N	—	9.32(11.84)	9.36	10.00	9.24	2.86	4.20(3.50)	3.29	1.19	0.74	1.23	+++++	++++
Peh-mi-fen	Non-man.	—	10.00(10.90)	9.26	9.70	13.26	4.94	2.15(1.65)	2.65	0.77	0.62	1.16	++	++++
	Non N	—	— (10.94)	9.05	10.17	10.35	4.12	3.10(1.45)	2.51	1.05	0.64	1.09	+	+
	Half N	—	9.76(13.29)	7.67	9.85	11.58	4.68	2.45(1.95)	2.56	1.26	0.69	0.95	+	+
	Normal N	—	9.27(12.58)	8.64	9.25	10.32	4.12	3.53(2.48)	2.35	1.19	0.69	1.02	++++	+
	Treble N	—	8.88(12.11)	9.24	7.59	10.32	2.78	4.14(2.50)	2.94	1.38	0.62	1.15	+++++	++++

Sown, Jan. 14, 1946. Sampling was made on Feb. 21 (38 days after sowing, i. e. seedling stage), Mar. 30 (75 days after sowing i.e. tillering stage), Apr. 29 (105 days after sowing, i.e. booting stage), and June 11 - 20 (148 - 157 days after sowing, i.e. maturity). [1] Leaf-blast infection at the tillering atage. [2] Results of the analysis with the 20-day seedlings grown under the 2nd crop condition in the same year. [3] Analysis was not made on account of lack of material.

Accordingly, such an intrinsic difference of leaf - blast resistance between the variety - groups may not be shown by such a chemical analysis as used in the present experiments, though the difference of resistance in the plants of the same variety grown under the different nutritional conditions seems to be somewhat correlative to the ash (silica) and nitrogen metabolism.

C. Effect of Soil Moisture

It has already been pointed out by Hemmi & Abe (1932), Suzuki (1937, *et passim*), etc., that the blast resistance of the rice plants is in parallel relation to the soil - moisture conditions under which they are grown, but these observations were made on some limited varieties of the Japanese lowland rice. The author made study on the effects of soil moisture on the varietal resistance with the use of many Varieties endemic to the different latitudinal districts. In the first place, inoculation was carried out on the potted seedlings (sown Oct. 28, 1947) grown under the different conditions of soil moisture, i. e., dry (very little water supplied to the seedlings so as to keep them alive), wet (normal upland condition) and flooded (normal lowland condition). Five pots of 1/200, 000 ha., 10 seedlings were grown in each, were arranged as 1 plot for each variety in the wire - gauze house, and inoculation was made 45 days after sowing.

As shown in table 99, increase of varietal susceptibility due to dryness of the soil is not so conspicuous in the Japanese upland and tropical varieties as in the Japanese lowland and "Horai" ones, and a considerable number of the formers are very resistant in any of the moisture conditions.

Similar experiments were also conducted in the field (the lst crop in 1944) with the different types of varieties, i. e., "Horai", Japanese upland and the native Formosan. Water supply was cut off at different stages of plant growth for different length of time during which period the soil was allowed to the natural dryness. The treatments of the experimental plots were as follows;

Plot 1. Water supply is suspended for 20 days commencing on the 5th day after transplanting.

Plot 2. Water supply is suspended for 20 days commencing on the 25th day after transplanting.

Plot 3. Water supply is suspended for 20 days commencing on the 45th day after transplanting.

Plot 4. Water supply is suspended for 20 days commencing on the 65th day after transplanting.

Plot 5. Water supply is suspended for 20 days commencing on the 85th day after transplanting.

Plot 6. Constantly irrigated in the ordinary manner (Control).

Plot 7. Kept almost dry except for the occasional irrigation which enabled the plants to keep alive.

Plot 8. Kept under the upland condition. Humidity is slightly higher than in plot 7.

The results of the experiments are shown in table 100.

Suzuki (1933) pointed out that the effect of dryness of the soil upon the susceptibility of the rice - seedlings is greater in the early stage of growth than in the later, and that on the necks of panicles it is greater in the stage previous to booting than in the subsequent stage. The author's present experiment was not only different from the above - named worker's in the methods, but also the plants were obliged to receive the occasional rainfall, accordingly, the results of it were considerably different from those of the above. The infection of the leaves was severest in the plots which were kept dry throughout the whole growth period, and it was also somewhat severe in those kept dry just before or close to the time of observation, since the plants which were kept dry in their younger stage could escape from the natural infection, consequently, they had already been recovered when observation was made. The susceptibility of necks of panicles was greately increased in the plants kept dry throughout their whole growth duration, but this tendency was not distinct in the resistant varieties. The yield of grains was minimum in the plots dried throughout, and also greatly reduced in the plots treated at their

Table 99. Results of inoculation of the potted seedlings cultured under different soil-moisture conditions.

Varieties (Habitat)	Dry			Moist			Flood		
	Height (cm)	No.of lesions ※	Sporulation	Height (cm)	No.of lesions ※	Sporulation	Height	No.of lesions ※	Sporulation
Shinriki (Japan, lowland)	55.2	0.151	++++	60.5	0.081	+++	75.0	0.082	++++
Kameji (Do.)	67.2	0.086	+++	72.2	0.038	+++	80.0	0.021	+++
Taichu Sp. No. 6 (Horai)	60.6	0.140	+++	75.2	0.110	+++	80.8	0.028	+++
Taichu No. 65 (Do.)	63.4	0.121	+++	66.4	0.069	+++	72.6	0.015	+++
Taichu No. 150 (Do.)	57.1	0.042	++	65.8	0.036	++	78.9	0.038	++
Kanan No. 8 (Do.)	65.0	0 120	+++	68.3	0.041	+++	76.0	0.081	+++
Noshinriki (Japan,upland)	61.5	0		75.8	0.010		80.1	0	
Caisen (Do.)	55.0	0.010	−	65.8	0		82.1	0	
Hujizo-mochi (Do.)	65.4	0		70.4	0		94.2	0	
Peh-mi-fen(Formosa. endemic)	61.0	0.004	±	76.5	0		85.8	0	
Man-tzu (Do.)	60.7	0.084	−	68.6	0		79.6	0.015	−
Tobura (Formosa, mount.)	65.4	0.104	+	73.6	0.010	+	80.8	0.010	±
Pehotsu-taiyar (Do.)	60.0	0.043	+	61.8	0.021	±	80.1	0	
Mao-tzu-tou (M China)	61.4	0.120	+	70.3	0.046	+	85.7	0	
Fei-lai-fung (Do.)	65.7	0.315	++	71.6	0.260	++	79.3	0	
Hsiang-keng (S.China)	70.0	0.281	+++	70.5	0.261	+++	78.9	0.198	+++
Tuan-tah-tsao (Do.)	70.8	0.018	++	80.6	0		89.6	0	
Kunmin-tsieh-kuan (Do.)	65.0	0.095	++	80.6	0		86.8	0	
Peh-mi-nian (Do.)	60.1	0		70.6	0		85.6	0	
Chieh-mi (Do.)	50.4	0.008	+	66.7	0		89.4	0 009	+
Kinin kuda (Philippine)	65.9	0.141	±	75.6	0.016	±	80.5	0	
Macan Menita (Do.)	75.0	0.012	−	85.1	0		97.8	0	
Macan Talipina (Do.)	55.4	0		62.3	0		85.6	0	
Takloban (Do.)	61.0	0		65.9	0		78.5	0	
Padi Bekka (Celebes)	54.1	0		61.4	0		84.5	0	
Padi Bogo (Do.)	53.4	0		69.5	0		78.8	0	
Lendak Kesaming(L.Sunda)	60.5	0.120	±	70.6	0		80 6	0 001	−
Padi Seri Mahi (Do.)	62.3	0.112	±	80.3	0		90.6	0	
Lum Chim (Indo-China)	45.3	0.051	±	65.7	0.062	±	79.0	0	
R.T.S. 27 (Do.)	60.6	0		70.4	0		85.5	0	
Mali Tong Bow (Siam)	70.0	0		85.5	0		101.5	0	
Heenati (India)	70.6	0.002	−	74.8	0		85.6	0	
P.T.B.9 (Do.)	65.8	0		85.7	0		89.5	0	
Keau N. 525(U.S.S.R.)	65.7	0.033	±	81.5	0		89.9	0.001	−
Blue Rose (Europe)	55.6	0.146	+	65.7	0.114	+	84.8	0.049	+

※Per 1 cm. of leaf length.

Table 100. The grade of natural infection of leaves and necks of ears and yield of grains of the different varieties grown under different soil - moisture conditions at different intervals of growth duration.

Varieties employed	Infection & yield	Plot no. 1	2	3	4	5	6	7	8
Taichu No. 65 (Horai)	Leaves [1]	+	+	+	++	++	++	+++	++
	Necks [1]	+	+	+	+	+	+	+++	+++
	Yield [2]	4,060	3,650	3,050	3,140	3,090	3,850	1,310	1,610
Taichu No. 150 (Horai)	Leaves	+	+	+	+	+	+	+	+
	Necks	+	+	+	+	+	+	+	+
	Yield	4,030	3,710	3,640	3,650	4,170	3,510	2,990	2,890
Urazo (Japan, upland)	Leaves	+	+	+	++	++	++	++	+
	Necks	+	+	+	+	+	+	+	+
	Yield	3,950	3,620	2,840	3,510	3,240	3,520	2,400	2,510
Fukutome (Japan, upland)	Leaves	+	+	+	+	++	++	+	+
	Necks	+	+	+	+	+	+	+	+
	Yield	3,270	3,440	2,860	3,480	3,130	3,240	2,950	2,780
Kagoshima Hakamuri No. 1 (Jap., upland)	Leaves	+	+	+	+	+	+	+	+
	Necks	+	+	+	+	+	+	+	+
	Yield	3,750	3,630	3,810	3,606	3,250	3,380	3,070	2,910
Kokko-mochi (Jap., upland)	Leaves	+	+	+	+	+	+	+	+
	Necks	+	+	+	+	+	+	+	+
	Yield	2,650	3,080	2,360	2,720	2,500	2,370	1,780	2,120
Keh - tzu A [3] (Formosa, native)	Leaves	+	+	+	+	+	+	+	+
	Necks	±	±	±	+	+	+	+	+
	Yield	4,160	4,210	3,070	2,740	2,780	3,700	2,100	3,000
Keh - tzu B (Formosa, native)	Leaves	+	+	+	+	+	+	+	+
	Necks	±	±	±	±	±	+	+	+
	Yield	4,210	3,860	3,430	3,760	3,910	3,740	2,860	3,000

Transplanted, Feb. 24, 1946. Exmined, May 25(leaf - blast) and June 15(Neck - blast). [1] The grade of infection was represented by number of + marks. [2] Kg. per ha. [3] A and B = A line native to Tah - chia and Ton - such district, pref. Taichung, respectively

best tillering stage as well as in those treated just after heading. This decrease of yield may be chiefly due to the physiological sensibility of the varieties to the dryness of the soil and partly due to the effect of infection of the blast disease. Such a change of resistance to the disease and yield of grains was most distinct in the "Horai" varieties, followed by the Japanese upland and the Formosan in the order named.

From these studies, it is concluded that in general the resistance of the varieties native to tropics is hardly effected by the environmental

factors, such as temperature, manuring and soil moisture, while the varieties endemic to temperate regions, especially the Japanese lowland varieties, are highly conditioned by those environmental factors.

Section 5. Inheritance of Varietal Resistance in the Crosses Between the Temperate and Tropical Varieties

As early as 1922. Sasaki confirmed from his crossing experiments with Japanese varieties that the resistance of the rice plant to the leaf-blast is due to a single dominant factor. On the other hand, Nakatomi (1926) reported that his inhreitance study on the F_3 progenies suggested the segregation-ratio of 9 resistant and 7 susceptible. Nagai (1926), however, hesitated to accept the Nakatomi's conclusion because of the fact that the ratio of segregation in the ahove-named experiment was widely deviated. Ikata *et al.* (1931), making a inheritance study by means of hybridization within the Japanese lowland varieties susceptible (Shinriki) and resistant (Kameji), pointed out that the resistant varieties may be bred by way of crossing between the resistant varieties and the susceple ones. Kuwatsuka (1942) also working with the Japanese varieties, confirmed that the higher the resistance of the parents employed for hybridization, the greater the percentage of the appearance of resistant individuals as well as the grade of resistance in their descendants. By means of crossing between the susceptible and resistant Indian varieties, Ramiah & Ramaswami (1936) succeeded in breeding the resistant lines which yield better than the susceptible parent, but were unable to confirm the mode of inheritance of resistance. Kawamura (1940) stated that the F_1 plants of Oryza satiav x O.minuta are as resistant as the male parent. These studies mentioned above, however, were not only confined to the leaf-blast resistance, but also wanting in giving a definite conclusion except those by Sasaki. Moreover, all the past studies were conducted by means of crossing between the varieties which are nearly-related to each other in their genetic affinity, though the breeding

performed by Iwatsuki (1942) was made by some selections among the crossings between the Japanese lowland varieties and the upland ones, the latter, *i.e.* "Sensho" and "Gaisen", being generally considered as those introduced from China and genetically different from the former.

The author intended to study the inheritance of blast resistance of rice plants in the hybrids between the distantly-related varieties, viz., the temperate and the tropical, for the purpose of breeding the highly resistant varieties of Japanese type which could accomodate themselves to the subtropical conditions (*cf.* chapt. VII. sect. 4). Three series of experiments were carried out with the use of different varieties native to both temperate and tropical regions and the observation was made not only on the leaf-blast resistance, but also on the neck - and node - blast resistance. In the first series of experiments, crossing was made during the 2nd crop of 1944 by the ordinary emasculation method. *i.e.*, removing the anthers by picking off the filaments with a pair of fine forcepts. The second - and third series were undertaken in the course of the lst - and 2nd crop in 1946, respectively, emasculation being made chiefly by means of the hot water treatment (Kondo, 1942)※ in combination with the above - named ordinary method. In the latter two, crossing was made between the varieties more congenial to each other as compared with those mated in the lst series in order to avoid certain errors or hindrances which might occur in the segregation studies on account of high sterility. The varieties employed for these three series of experiments were as follows:

※The author was greatly indebted to prof. H Oka, Taichung College of Agriculture for showing the method of emasculation as well as supplying with several of his F_1 seeds.

Table 101 The lineage of the varietes employed for the study of inheritance of resistance.

Name	Habitat	Type or lineage	Expt.no.※
Aikoku No.1	Japan	A line of a lowland variety	2, 3
Bozu No.5	Do.	Do.	2
Ginbozu	Do.	Native lowland	2
Kinugasa-wase	Do	Do.	3
Kisshin	Do	A cross-bred lowland variety	3
Kinoshita-mochi	Do.	Native lowland	2, 3
Mansaku	Do.	Do.	3
D 9	Do.	A cross-bred line(?)	3
Hirayama	Do.	Native upland	2, 3
Urazo	Do.	Do.	3
Taichu Sp. No. 6	Formosa	"Hori". a line of "Asahi" (Jap.lowl.)	1
Taichu No. 65	Do.	"Horai". a hyb. within Jap. lowl.	1, 3
Taichu No. 150	Do.	"Horai". a crobb-bred lowl.	1
Taichu No. 153	Do.	Do.	3
NC No.4	Japan	A cross-bred lowl. betw. Ital. x Jap.	3
Blue Rose	Europe	Native lowland	1, 3
Fu-rutau	M. China	Do.	1, 2
Peh-mi-fen	Formosa	Do.	3
Tah-li-wan	Do.	Do	3
U-tzen	Do.	Do.	3
Pai-ku	Do.	Do.	1, 2
Tubura	Do.	Native lowland in mountain region	1, 3
Habun No.1	Do.	A line of native lowl.in mount.	2
Komonawai	Do.	Native upland in Mountain region	3
Po-yang-tsao	M. China	Native lowland	3
Koddi	Hainan	Do.	2
Chien-sieng	M. China	Do.	1
Davao	Philipp.	Do.	2
Garum Balay	Do.	Do.	3
Malagkit Sinoguing	Do	Do.	3
Malagkit Pirulutung	Do.	Do.	2
Ketan Kaetoeh	Do.	Do.	1
Paenot Hitam	Do.	Do.	2
Asse Banda	Celebes	Do.	2, 3
Bali Atjeh	Do.	Do.	2
Boenar	Java	Do.	2
Boera Ropo	Les. Sunda	Do.	2
Som Cau	F. In.China	Do.	3
Plaiuk Kai	Siam	Do.	1
Pacchai Perunel	Ceylon	A selection of Ceylon A. E. S.	1

※ Series - number of experiments for which the verieties employed.

A. The First Series of Experiments

(a) F_1 generation

(1) Leaf - blast resistance

During the lst crop season in 1945, the F_1 plants were grown under the glass house condition together with their parent varieties, and inoculated at the tillering stage.

Table 102. Results of the inoculation experiments with the leaves of the F1 plants.

Parents & crosses	Experiment A			Experiment B			
	No. of lesions	Length of les. (cm)	Sporulat	% of inf. leaves	Lesion (cm)	Colour of lesion	Sporulation
TaichuSp. No. 6	24.6	0.15	++	34.3	1.6x0.4	Grey	++++
Taichu No. 65	16.0	0.15	+	28.4	1.3x0.3	Grey	++++
Taichu No. 150				25.0	1.0x0.3	Gr. brown	+++
Fu - ru - tau				30.0	1.2x0.3	Gr. brown	+++
Blue Rose	1.0	0.08	+	7.4	0.8x0.2	Gr. brown	++
Tobura	2.0	0.08	—	3.0	0.5x0.3	Brown	±
Ching - sieng	0·8	0.05	±	0	—	—	—
Ketan Kaetoeh				0	—	—	—
Plaiuk Kai				0	—	—	—
Pacchai Perunel				5.1	0.4x0.2	Brown	+
Taichu 65 x Paichu 150	4.0	0.12	++	12.0	0.7x0.3	Grey	+++
Fu - ru - tau x Taichu 65				70.1	1.4x0.4	Grey	+++
Taichu 65 x Tobura	0	—	—				
Tobura x Taichu 65	1.0	0.15	±	1.2	0.3x0.2	Brown	+
Taichu 65 x Blue Rose	7.5	0.13	+				
Blue Rose x Taichu 65	1.0	0.10	—	8.5	1.0x0.4	Br. Grey	++
Taichu Sp. 6 x ching - sieng	0	—	—	0	—	—	—
Ching - sieng x Taichu Sp. 6	1.5	0.10	±				
Taichu 65 x Ching - sieng	0	—	—				
Ching - sieng x Taichu 65	3.7	0.10	±				
Taichu 65 x ketan kaetoeh				2.5	0.4x0.3	Brown	±
Ketan Kaetosh x Taichu 65				1.1	0.7x0.3	Brown	+
Plaiuk Kai x Taichu 65				0	—	—	—
Taichu 65 x Plaiuk Kai				18.6	0.6x0.2	Br. Grey	+
Pacchai Perunel x Taiehu 65				20.5	0.6x0.3	Brown	+
Tobura x Plaiuk Kai				0	—	—	—
Plaiuk Kai x Tobura				0	—	—	—

Inoculation: Expt. A. - Jan. 19, 1945; Expt. B. - May 1, 1945.

It is inferred, so far as the present experiments are concerned, that the F_1 plants resulted from the hybridization within the temperate type are susceptible, while those within the tropical as well as those between the different types, *i. e.* temperate and tropical, are all resistant, even if the crossing is made by use of some susceptible Japanese varieties as one of the parent (*vide.* fig. 25).

(2) Neck - blast resistance

The number of the infected ears emerged from the plants used for the above - named inoculation was counted in order to get some informations about the inheritance of neck - blast resistance (*vide.* tab. 103).

Table 103. The number of the infected ears emerged from F_1 plants inoculated on leaves at the tillering stage.

Parents & crosses		Date of heading	No. of ears examined	No. of infected ears	% of infected ears
Parents	Taichu Sp. No.6	5.07	134	62	46.3
	Taichu No. 65	5.20	180	56	31.1
	Taichu No. 150	5.18	120	60	50.0
	Fu - ru - tau	5.20	122	4	3.3
	Tobura	5.29	215	0	0
	Blue Rose	5.22	64	8	12.5
	Chin - sien	5.02	112	0	0
	Ketan Kaetoeh	6.25	110	0	0
	Plaiuk Kai	5.24	130	0	0
	Pacchai Perunel	5.07	90	3	3.3
F_1	Taichu No. 65 x Taichu No. 150	5.23	76	44	57.9
	Fu - ru - tau x Taichu No. 65	5.18	20	16	80.0
	Tobura x Taichu No. 65	5.30	27	12	44.4
	Blue Rose x Taichu No. 65	5.22	35	4	11.5
	Taichu Sp. No. 6 x Chin - sien	5.02	58	0	0
	Taichu No. 65 x Ketan Kaetoeh	5.21	24	0	0
	Ketan Kaeto eh x Taichu No. 65	5.19	148	0	0
	Plaiuk Kai x Taichu No. 65	5.21	32	0	0
	Pacchai Perunel x Taichu No. 65	5.07	332	108	32.5
	Tobura x Plaiuk Kai	5.29	22	0	0
	Plaiuk Kai x Tobura	5.29	26	1	3.6

The data given in the above table do not necessarily represent the true resistance of the ears, since most of the infection mentioned above might be probably derived from the infection which took place on the sheath of the plants during their younger stage; hence, the former is considered to be rather directly affected by the degree of leaf - blast resistance of the varieties under consideration. Nevertheless, in considering the fact that in some varieties, such as "Fu-ru-tau," the number of the infected ears has no correlation with the susceptibility of the leaves, accordingly the results mentioned above are considered to have a certain meaning upon the varietal resistance of the ears. Consequently, it may be concluded at least that the neck-blast resistence is dominant.

(b) F_2 generation

In order to ascertain the segregation in the F_2 generation, the F_2 progenies derived from the self - pollinated F_1 plants mentioned above were grown in the paddy field during the 2nd crop season of 1945, but unfortunately the infection which is considered sufficient enough for

determining the segregation - ratio could not be obtained chiefly due to insufficient nitrogenous fertilizer and removal of water drops on the leaves by monsoon in the consecutive days during tillering and heading stages. Nevertheless, some of the F_2 progenies were tested under the glass - house conditions during autumn and winter of the same year. The seeds of certain crossings were sown together with those of their parent varieties on the upland seed - bed prepared in the glass house and the seedlings were inoculated when they attained the 4 - 5 - leaf stage. The artificial inoculation was repeated thrice (Dec.8, 12 and 15) so as to minimize the chance of escaping of seedlings from infection. On Dec. 21, the reaction of the leaves of the F_2 populations to the blast disease was determined by dividing them into three types according to the nature of lesions, i.e., seedlings having typical large grey (or purplish grey) lesions with abundant conidia (susceptible), those showing brown (or orange brown) lesions (generally small) with scanty sporulation (resistant) and those unaffected. It was inevitable, however, that this classification was more or less arbitrary, since the infection types in certain seedlings were hardly discernible.

Table 104. Results of the inoculation experiment with the F_2 population in the glass house.

Parents & crosses	Sterility (%)※	No.of plants tested	No.of segregated seedlings		
			Grey lesions	Brown lesions	No lesions
Taichu Sp.No.6	8.9	516	486	0	30
Taichu No.65	6.0	586	520	0	66
Blue Rose	8.1	386	216	10	160
Tobura	16.9	324	0	98	226
Chieng-sieng	16.1	220	0	46	174
Ketan Kaetoeh	19.6	286	0	23	263
Pacchai Perunel	23.6	282	5	97	180
Plaiuk Kai	23.1	240	0	12	228
Taichu No.65 x Blue Rose	19.1	240	98	29	113
Tobura x Taichu No.65	17.2	240	11	54	175
Taichu Sp.No.6 x Chin-sien	39.3	171	18	76	77
ketan Kaetoeh x Taichu No.65	11.2	544	5	78	461
Pacchai Perunel x Taichu No 65	76.2	114	8	31	75
Plaiuk Kai x Tobura	88.9	68	0	7	61

※ Per cent of sterile grains in the ears of the healthy F_1 plants.

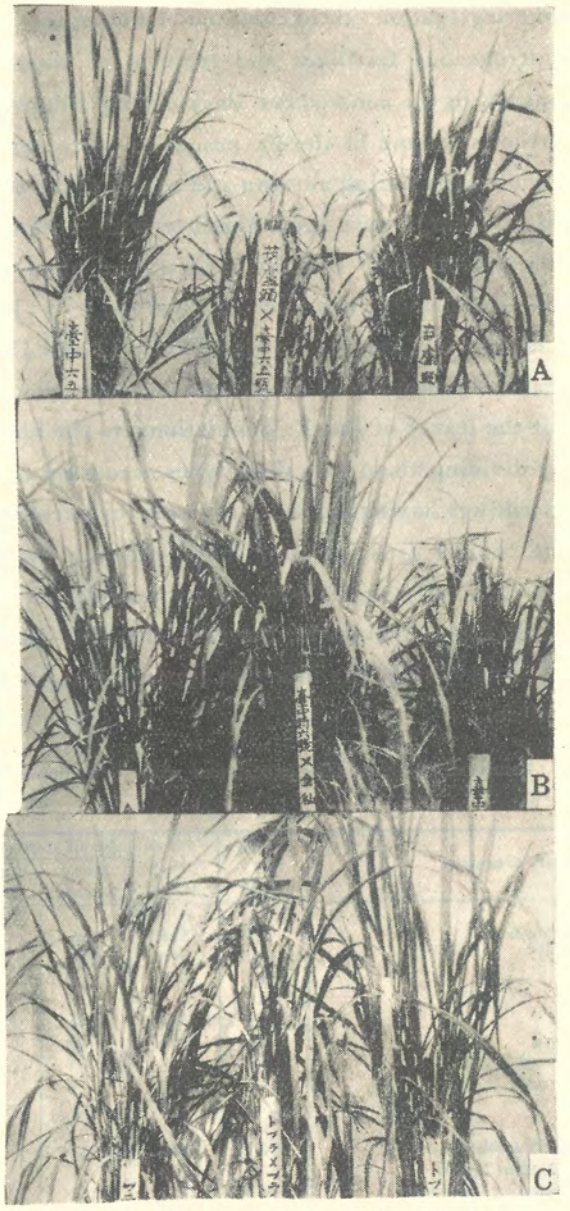


Fig. 25. Leaf - blast resistance of the F_1 plant derived from the cross

A. Within the susceptible varieties (Fu - ru - tau, right x Taichu No. 65, left).

B. Between the susceptible (Taichu Sp. No. 6, right) and resistant (Ching - sien, left) varieties.

C. Within the resistant varieties (Tobura, right x Plaiuk Kai, left).

As shown in table 104, it is apparent that the F2 progenies derived from the hybridization within the susceptible (temperate) varieties are susceptible, and those from the crossing within the resistant (tropical) are resistant. So far as the present experiments are concerned, however, it is rather difficult to decide definitely the mode of inheritance in the crosses between the susceptible and the resistant, since a considerable number of individuals in the plots of the susceptible parent varieties apparently escaped infection, probably due to cool weather somewhat unfavourable for infection and disease development. Morever, as already mentioned, some resultant data were so indistinct that they make the determination more difficult. As for the number of unaffected individuals in the crosses between the temperate and tropical and tropical varieties or within the tropical, it is practically impossible to decide definitely whether these individuals are due to the heritable resistance or merely due to the escaping from infection because of a technical difficulty of making uniform inoculation. Nevertheless, it is inferable at least that the inheritance of resistance may not be governed by the monohybrid basis, since the number of the susceptible individuals in the crosses between the susceptible and resistant varieties is too small to admit such a mode of inheritance.

B. The Second Series of Experiments

(a) F_2 generation

(1) Leaf-blast resistance

In the lst crop, 1947, the F2 progenies were cultured in the paddy field, nitrogen fertilizer being given quadruple as much as the ordinary amount. The seedlings were transplanted on Apr.24 in rows of 2.4.2 m. long and 25 cm. apart, plants being spaced 20 cm. apart. Ten or more rows were provided for each offspring, accompanied by one or two rows for each of the parent verieties. In order to get a heavy epidemic, water supply was frequently suspended and the field inoculations were repeated on the rainy days during the tillering-and booting stage. On

July 19, the plants were classified according to the following grades of leaf-blast infection.

Grade 1. Almost no lesion. Grade 2. A few lesions.

Grade 3. Several (5 - 10) lesions Grade 4. A considerable number (more than ca. 10) of lesions.

Table 105. Number of F_2 individuals grouped according to the grade of leaf-blast infection in the field during the 1st-crop season, 1947.

Parents & crosses	Infection grades 1	2	3	4	Total
Kinoshita-mochi		51	3		54
Boera Ropo	43				43
Kinoshita-mochi x Boera Ropo	132	29	36	12	209
Asse Banda	50				50
Bozu No. 5			43	2	45
Asse Banda x Bozu No. 5	77	14	10	4	105
Aikoku No. 1		70	14	1	85
Asse Banda x Aikoku No. 1	124	16			140

In consideration of the fact that in the crossings between the resistant and susceptible varieties the number of the resistant individuals exceeds greatly that of the susceptible and also that of the intermediate in some extents, it is suggested that the resistance may not be governed at least by a single dominant factor. If the segregation in Kinoshita-mochi x Boera Ropo is considered on the basis of the 9 : 3 : 3 : 1 ratio, the observed ratio is close to the theoretical (Chi square = 4.38, P = 0.23), though in the case of Asse Banda x Bozu No.5 is otherwise.

(2) Neck-blast resistance

At the maturity of the plants grown in the above-named paddy field, all the individuals were pulled out and classified according to the percentage of the neck-blast infection calculated by the following formula, i. e. $\frac{\text{Number of infected necks per plant}}{\text{Number of ears per plant}} \times 100$. The resultant data obtained from the observation on the parents and F_2 progenies are given in the following table and fig. 25.

Table 106. Distribution of parents and F_2 individuals into the percentage of the neck-blast infection.

Parents & F2	Number of individuals in each class																					Total
	0%	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	
Asse Banda	16	24	10																			50
Bozu No.5														14	26	5						45
Asse Banda x Bozu No.5	13	14	11	5	7	2	2	4	3	4	5	1	4	3	3	2	2		1	5		91
Kinoshita-mochi												10	23	16	2	3						54
A.Banda x Kinoshita-mochi	73	58	25	26	23	19	13	15	13	9	3	6	8	1	5	4	5	2	1			309
Aikoku No.1									5	15	17	6	3	2								48
A.Banda x Aikoku No.1	77	29	15	29	6	15	12	9	7	7	5	3		2	2	5	1	2		2		230
Boenar	28	14	8	2	1																	53
Kinoshita-mochi x Boenar	65	22	14	23	15	4	7	15	5	8		3	2	4	1	2	1			1		192
Malagkit Pirulutung	37	11	2																			50
K.-mochi x M.Pirulutung※	151	93	53	80	43	28	22	28	7	11	5	6	2	1	4							534
Boera Ropo※	36	7																				43
K.-mochi x Boera Ropo	105	45	34	33	40	14	14	15	9	6	9	3	4	4	3	2	1	1	1	2		345
Davao	6	28	10																			44
Kinoshita-mochi x Davao	53	21	17	7	4	5	3	2	1	2												115
Hirayama					14	23	15	1														53
Asse Banda x Hirayama	177	65	34	40	11	27	12	5	3	8	3	2	4	1	1	1	1					395
Fu-ru-tau※	6	18	7	2																		33
Asse Banda x Fu-ru-tau	62	23	27	27	8	1	4	1														153
Koddi	8	18	4	6	3																	39
Asse Banda x Koddi	37	37	18	17	6	3	6	6	2													132
Pai-ku	8	10	8	8	4																	38
Plaiuk Kai	24	17	4	1	2	1																49
Paiku x Plaiuk Kai	76	19	18	13	2	4	6	2	1													141

※ Observation could not be made completely owing to retardation and ununiformity of heading

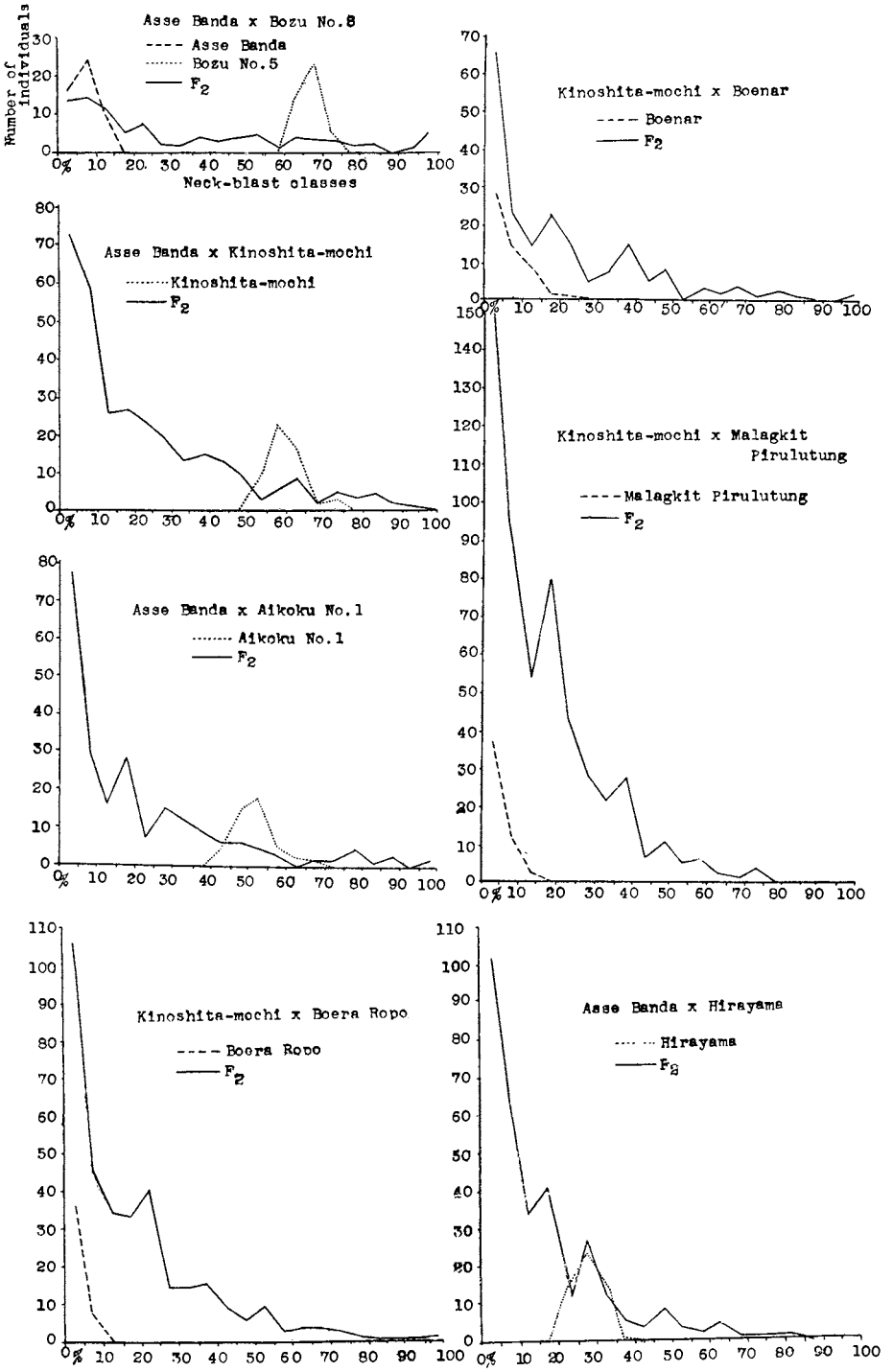


Fig. 26. Distribution of parents and F_2 individuals in 5-per cent classes of neck-blast infection.

By observing these figures, it can be seen that there is a similarity in these curves, namely, these curves showing the presence of a larger number of the resistant individuals, a large number of intermediate individuals involving two different groups, and a small number of susceptible ones. The minima in the curves shown in these figures are considered to indicated the groups of the respective phenotypes. For instance, in the cross of Asse Banda x Bozu No. 5, the minima fall on 30%, 60% and 85%. As shown by table 107, when the number of individuals in each group is computed according to this assumption, the numerical distribution in many of the crosses between the resistant and susceptible varieties represents a 9 : 3 : 3 : 1 ratio which can be explained on the basis of two main factors. The goodness of fit of these crossings will be shown in the same table.

According to the above - named calculation, three crosses, i. e., Asse Banda x Bozu No. 5, Asse Banda x Kinoshita - mochi, Kinoshita - mochi x Boenar, were fairly close to the theoretical ratio, especially P of the frist - named crossing showed a highly significant value. On the other hand, Asse Banda x Aikoku No. 1 and Asse Banda x Hirayama showed a rather poor fit. This fact was probably due to the wide deviation of susceptibility of Aikoku No. 1 and the moderate resistance of Hirayama, resp., as shown in the figures. As regards the fit of the crosses of Kinoshita-mochi x Malagkit Pirulutung and Kinoshita - mochi x Boera Ropo it is rather difficult to decide, but the curves of segregation seem to indicate the dihybrid mode of inheritance. In the crossing between Kinoshita-moehi x Davao, the segregation into four phenotypes can not be clearly evidenced, though the ratio indicates 12 : 4 which also suggests the presence of two alleromorphic factors. On the other hand, most of the individuals derived from the crossing within the resistant varieties, i. e., Asse Banda x Fu - ru - tau, Asse Banda x Koddi and Pai - ku x Plaiuk Kai, showed a high resistance.

Table 107. Number of individuals grouped by the numerical distribution of neck - blast infection and calculation of goodness of fit to a theoretical 9 : 3 : 3 : 1 ratio.

Crosses	Grouping	No. of individuals		$(O-C)^2$	X^2 & P
		Observed	Calculated	C	
Asse Banda x Bozu No. 5	Resist.	52	51.19	0.0128	X^2=0.7965 P=0.841
	Mod. res.	19	17.06	0.2183	
	Mod. sus.	14	17 06	0.5488	
	Suscept.	6	5.69	0.0165	
	Total	91			
Asse Banda x Kinoshita - mochi	Resist.	156	173.81	1.8269	X^2=5.0792 P=0.167
	Mod. res.	68	57.94	1.7467	
	Mod. sus.	67	57.94	1.4167	
	Suscept.	18	19.31	0.0889	
	Total	309			
Asse Banda x Aikoku No. 1	Resist.	121	129.38	0.5428	X^2=6.5508 P=0.088
	Mod. res.	37	43.13	0.8713	
	Mod. sus.	58	43.13	5.1267	
	Suscept.	14	14.36	0.0100	
	Total	230			
Kinoshita - mochi x Boenar	Resist.	101	108.00	0.4852	X^2=1.6566 P=0.652
	Mod. res.	42	36.00	0.8571	
	Mod. sus.	35	36.00	0.0286	
	Suscept.	14	12.00	0.2857	
	Total	192			
Kinoshita - mochi x Malagkit Pirulutung	Resist.	297	300.38	0.0380	X^2=10.6093 P=0.013
	Mod. res.	123	100.13	5.3381	
	Mod. sus.	78	100.13	4.8910	
	Suscept.	36	33.38	0.3422	
	Total	534			
Kinoshita - mochi x Boera Ropo	Resist.	184	194.06	0.5211	X^2=10.3424 P=0.016
	Mod. res.	87	64.69	7.6942	
	Mod. sus.	53	64.69	2.1125	
	Suscept.	21	21.56	0.0146	
	Total	345			
Asse Banda x Hirayama	Resist.	242	222.19	1.7662	X^2=6.6885 P=0.093
	Mod. res.	74	74.06	0.0005	
	Mod. sus.	55	74.06	4.9053	
	Suscept.	24	24.69	0.0166	
	Total	395			

In this connection, however, it is to note that the susceptible parent has not shown a complete susceptibility. Livingston(1942) and some other workers also met with some difficulties in interpreting the mode of segregation because of the impossibility of securing 100 per cent infection in the susceptible parent, even in the case of the most susceptible varieties. Such a technical difficulty is of rather common occurrence in the study on the inheritance of resistnce to such diseases as those can be

quantitatively graded as regards the resistance and susceptibility. In the present experiments, the above-named phenomenon was considered to be partly due to such a technical cause, since in the two susceptible parent varieties, viz., Bozu No. 5 and Kinoshita-mochi, the plants were pulled somewhat early prior to the complete maturity in order to avoid falling down due to the stemrot infection (*Corticium* (*Hypochnus*) *Sasakii*). If these two varieties were still allowed to remain in the field until complete maturity, they would reveal the susceptibility somewhat higher than that shown in the table. Moreover, in the present experiments, the effect of the environmental factors upon the susceptibility of individuals was proved almost negligible (*vide.* the later paragraph); accordingly, the curve of variation showing the precentage of infection of the susceptible parents may be considered as representing substantially the intrinsic susceptibility of them. Besides, it is also to be remembered that the above-named curves indicate rather wide deviations and the mode of class-value is not always distinct enough for interpreting the segregation phenomena of the F_2 individuals, but such a defect would be decreased by use of the sufficient number of individuals. Then the next question may arise on the fact regarding the appearance of a considerable number of segregates which are more susceptible than the susceptible parent. Schlehuber (1935), studying the inheritance of resistance of wheat to four bunt biotypes, found the similar phenomenon and interpreted as follows: The susceptible parent may have a partial factor for resistance, thus revealing a certain grade of resistance, but in the progenies this factor is recessive and combined with the other recessive, consequently, they become completely susceptible, exceeding the grade of the susceptible parent. Likewise, according to Farrie (1939) who studied the inheritance of smut resistance in oats, this phenomenon may be probably due to the fact that the susceptible parent has a factor pair for resistance or partial resistance which is not possessed by the resistant parent. Tha presence of such factorial relations may also be considered in the present experiments. Although there are some points to be criticized as mentioned above, on the whole, it is almost unquestionable that the mode of segregation in the crossing between the

resistant and susceptible varieties indicates the presence of two main factors which govern the neck - blast resistance.

Lastly, there is one more points to be considered in connection with this problem. It is often noticed that the occurrence of the neck - blast infection is largely effected by the so - called "disease - escaping" which is induced by the environmental conditions during the heading and maturity stages of the individual plants. As mentioned in chapt. V, the necks of ears are susceptible when they are still enclosed with the sheaths, but become resistant with the lapse of days after heading. Hence, strictly speaking, it might be difficult to elucidate the heritable resistance of the necks of the segregates, even if they were cultured under the controlled condition, since one has to encounter with difficulty of changing the heading time of different individuals at will, still more of making the different ears of the same plant emerge simultaneously. As a matter of fact, in most cases the date of heading of the F_2 individuals is strikingly at variance with one another, extending over more then one month, especially in those between the distantly - related varieties. It was therefore considered at the start that the environmental factors during the heading and maturity stages of each individual plant migght influence infection to a great extent, and thus making the determination of the segregation ratio unreliable. For this reason, the date of heading* of each individual plant was first recorded at 5 - day intervals, and the correlation between the precentage of infection of the F2 individuals and their heading time was computed. An example of such correlation will be shown in table 108. The correlations in the other crossings were also substantially the same as in the above - named. Judging from such a meagre negative correlation between the heading time and the neck - blast infection as evidenced in these crossings, it seems that the environmental conditions have rendered practically no influential effect upon the segregation. It is also expected that if the environments had to do with it, the curves represented by the segregates might have been more or less biassed.

*The date of heading is the day on which one - thired of the ears of the individual plant emerged.

Table 108. Correlation between the percentage of neck-blast infection and the date of heading in the F_2 progenies of Asse Banda x Kinoshita-mochi.

X(Date of heading)	Y(Percentage of infection) 2.5	7.5	12.5	17.5	22.5	27.5	32.5	37.5	42.5	47.5	52.5	57.5	62.5	67.5	72.5	77.5	82.5	87.5	92.5	97.5	F
June 25	1	5	1	1	3	1	1	1	1	1		2				1	1				20
July 1	3	9	3	3	4		1	3	1	2			1			1	1				32
July 6	17	13	9	9	5	6	5	5	6	2	2		3			2	1	1	1		87
July 11	25	15	7	7	7	7	4	6	4	2		3	3		5		2	1			98
July 16	14	13	3	5	2	3	1			2	1	1	1	2							48
July 21	8	2	1	1	2	2			1												17
July 26	4	1	1						1												7
July 31	1																				
F	73	58	25	26	23	19	13	15	13	9	3	6	8	1	5	4	5	2	1		309

$r = -0.242 \pm 0.054$

(3) Node - blast resistence

The plants employed for the experiments of neck - blast resistance mentioned above were also used at their maturity for the study on the inheritance of node - blast resistance. The individual plants were classified according to the percentage of infection at intervals of 5 - per cent, the percentage being calculated by the following formula, *i. e.*

i.e. $\frac{\text{Number of infected tillers per plant}}{\text{Number of tillers per plan}} \times 100$. The infected tillers were counted without regard to the number of the blasted nodes of a single tiller. The resultant data are given in table 109 and fig. 27.

By observing fig.27, it can be seen that there is a striking similarity in the curves of the different crossings. In the crosses between the resistant and susceptible varieties, the minima usually fall on 25%, 40% and 75%, except those of Asse Banda x Kinoshita-mochi and Kinoshita-mochi x Malagkit Pirulutung, in which the relation was somewhat different from the above-named. The grouping of the phenotypes and the calculation of goodness of fit to the theoretical ratio will be shown in table 110.

From table 110, it is assumed that the node - blast resistance is governed also by two main factor pairs. Especially Chi square and F of Asse Banda x Bozu No. 5, Asse Banda x Kinoshita-mochi, Kinoshita-mochi x Davao and Asse Banda x Fu-ru-tau showed a close agreement with the theoretical ratio. The fact that the numerical distribution in these crosses showed a good fit to the theoretical in spite of the fairly wide variation in the infection of the susceptible parent lines, seems to be somewhat incomprehensible, but this might be probably due to the insufficiency of the number of individuals of the parental lines used for the examination, as has already been mentioned in the neck-blast resistance. So far as the present classification of the phenotypic segregation was concerned, however, the fits of Kinoshita-mochi x Malagkit Pirulutung, Kinoshiha-mochi x Boenar, and Kinoshita-mochi x Boera Ropo were as poor as difficult to admit the theoretical ratio, though the mode of curves which represents the segregation in them are similar to those of the crosses which showed the good fits as mentioned above. It is not clear whether such

Table 109. Distribution of parents and F_2 individuals into the percentage of the node-blast infection.

Parents & F_2	Number of individuals in each class																					Total
	0%	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	
Asse Banda	36	24	7	5																		72
Bozu No.5														8	18	4	4	2				36
Asse Banda x Bozu No.5	22	11	5	9	7	2	8	9	3	7	1	2	2	2		2	1				1	94
Kinoshita-mochi													4	14	18	10	6	2				54
A.Banda x Kinoshita-mochi	49	32	21	42	29	22	17	16	13	28	4	10	5	4	7	3	2	2			2	308
Fu-ru-tau ※																						
A. Banda x Fu-ru-tau	17	15	12	17	15	7	10	14	6	10	2	6	4	4	2	2	3	1	1	5		153
Davao	17	6	4																			27
Kinoshita-mochi x Davao	22	8	14	11	13	10	6	10	4	6	1	4	4					1	1		4	119
Boenar※																						
K.-mochi x Boenar	42	7	24	17	10	5	12	9	11	20	2	8	4	7	6	1	2	3			3	193
Malagkit Pirulutung※	40	2																				42
K.-mochi x M.Pirulutung	70	26	27	47	53	26	43	43	27	51	12	28	11	18	15	12	8	5	2	13		537
Boera Ropo※																						
K.-mochi x Boera Ropo	114	15	18	21	16	17	17	26	11	24	2	22	5	17	9	2	6	4			2	348
Hirayama									5	9	8	7	3	2	1	1	2	1				39
Asse Banda x Hirayama	45	19	20	31	32	25	24	30	10	33	13	23	13	18	26	11	9	1	2	6		391
Koddi				3	2	6	4	3	1	1												20
Asse Banda x Koddi	34	10	8	12	9	3	6	2	8	9	3	1	4	6	4							119

※ Observation could not be made completely owing to retardation and ununiformity of maturity.

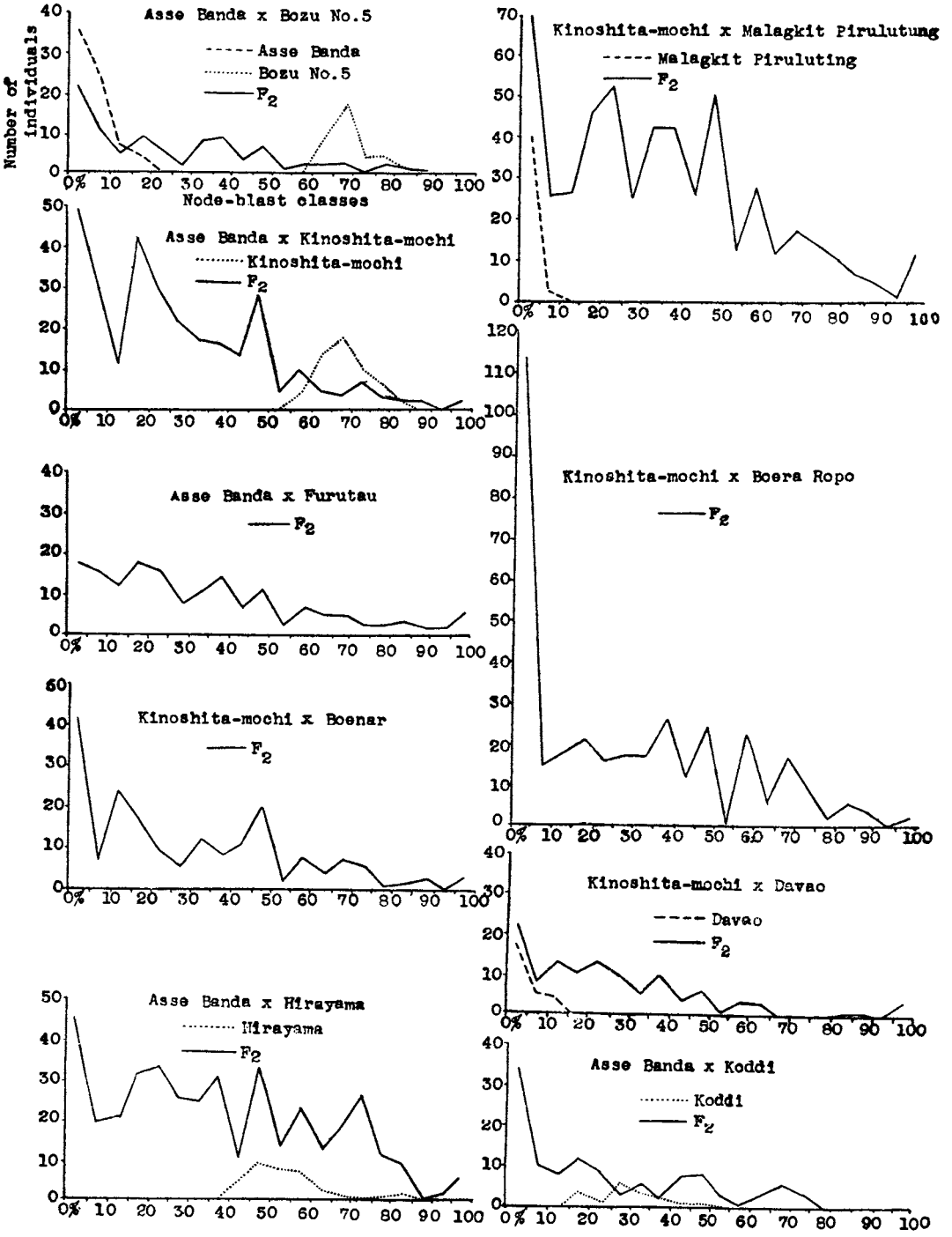


Fig. 27. Distribution of parents and F_2 individuals in 5-per cent classes of node-blast infection.

Table 110 Number of individuals grouped by the numerical distribution of node-blast infection and calculation of goodness of fit to a theoretical 9 : 3 : 3 : 1 ratio.

Crosscs	Grouping	No. of individuals		(O - C; 2	x² & P
		Observed	Calculated	C	
Asse Banda x Bozu No.5	Resist.	54	52.88	0.0237	x²=0.7546 P =0.849
	Mod. res.	19	17.62	0.1081	
	Mod. sus	17	17.62	0.0218	
	Suscept.	4	5.88	0.6010	
	Total	94			
Asse Banda x Kinoshita-mochi	Renist.	173	173.25	0.0004	x²=0.2484 P =0.952
	Mod. res.	55	57.75	0.1310	
	Mod. sus.	60	57.75	0.0877	
	Suscept.	20	19.25	0.0293	
	Total	308			
Asse Banda x Furutau	Resist.	76	86.06	1.1748	x²=2.9665 P =0.398
	Mod. res.	31	28.69	0 1860	
	Mod. sus.	34	58.69	0.9828	
	Suscept.	12	9.56	0.6228	
	Total	153			
Kinoshita-mochi x Boenar	Resist.	100	108.56	0.6750	x²=17.4645 P = 0.0006
	Mod. res.	26	36.19	2.8692	
	Mod. sus.	58	36.19	13.1439	
	Suscept.	9	12.06	0.7764	
	Total	193			
Kinoshita-moahi x Malagkit Pirulutung	Resist.	335	302.05	3.6060	x²=15.2415 P = 0.002
	Mod. res	90	100.69	1.2016	
	Mod. sus.	97	100.69	0.1351	
	Suscept.	15	33.57	10.2976	
	Total	537			
Kinoshita-mochi x Boera Ropo	Resist.	184	195.75	0.7053	x²=13.2570 P = 0.004
	Mod. res.	60	65.25	0.4224	
	Mod. sus.	90	62.25	7.7586	
	Suscept.	12	21.75	4.3707	
	Total	346			
Kinoshita-moch x Davao	Resist.	68	66.94	0.0168	x²=1.3979 P =0.710
	Mod. res.	26	22.31	0.6103	
	Mod. sus.	19	22.31	0.4911	
	Suscept.	6	7.44	0.2790	
	Tetal	119			
Asse Banda x Koddi	Resist.	52	66.94	3.3344	x²=14.8328 P = 0.002
	Mod. res.	24	22.31	0.1392	
	Mod. sus	28	22.31	1.7847	
	Suscept.	15	7 44	9.5745	
	Total	119			

curves are due to the deviation of the node-blast infection or to the factorial relation pertaining to the number of the factor which governs the partial resistance, since the accurate datermination of the grade of resistance of the resistant (tropical) parents used for these crossings was unable

owing to the retardation and ununiformity of heading. The result of the crossing Asse Banda x Koddi (which was made within the varieties rasistant to leaf-blast) also showed the segregation somewhat similar to that in the crossing between the resistant and susceptible varieties, though the ratio showed a bad fit to the dihybrid basis. The above-named segregation might be probably due to the moderate susceptibility of Koddi to the node-blast, though this has not yet been experimentally confirmed on account of the insufficient number of individuals and the wide variation of infection.

In the next place, it is also to note that in many of the crossings a few minima are found at the points other than those representing the boundaries of the different phenotypes, especially at the class-values of 10.1 - 15.0 per cent. This phenomenon is considered chiefly due to the chance occurrence resulted from the experimental procedure employed for reading infection-grades, and partly to the deviation of the natural infaction, but possibly not to the factorial relation. This relation may be explained by clarifying the correlation between the number of tillers of each individual plant and the percentage of node-blast infection. For this purpose, an investigation was made in the crossing Asse Banda x Kinoshita-mochi in which a distinct minimum is found at the class of 10.1 - 15.0 per cent.

Table 111. Correlation between the percentage of node-blast infection and the number of tillers per plant in the crossing Asse Banda x Kinoshita-mochi.

X (Number of tillers) \ Y (Percentage of infection)	2.5	7.5	12.5	17.5	22.5	27.5	32.5	37.5	42.5	47.5	52.5	57.5	62.5	67.5	72.5	77.5	82.5	87.5	92.5	97.5	F
5	2			2				1	1											1	7
6										2							1				3
7	5		2			5			2			2									16
8			2		4			3		5					3						17
9	8		7		4		4	1	3			1				1		1		1	31
10	6	5		8		5		3		7		4		1		2		1			42
11	4	7		6		5	1	3	2	2	3				1						34
12	12	9		10	11				2	7		1		1	1		1				55
13	4	1		6	7	1	7	2		1	1		3		1						34
14	1	2	5		3	2	1	1	1	3		2	1		1						23
15	2	1	3	4		2	4	1		1				1							19
16	2	2	2										1								7
17	1	2		2		1								1							7
18		1		2					1				1								5
19	1	1		1				1													4
20				1		1															2
21	1	1																			2
22									1												1
F	49	32	21	42	29	22	17	16	13	28	4	10	5	4	7	3	2	2	0	2	308

$r = -0.129 \pm 0.056$

In the above table, four continued blank spaces (marked with the dotted line) are seen at the class-values of 10, 11, 12 and 13 of X-axis (number of tillers) which correspond to the class-value of 10.1-15.0 per cent of Y-axis (percentage of infection). These blanks are resulted merely from the calculation of percentage of infection according to the difference of number of tillers per individual plant as shown by the following table.

Table 112. Detaild information about the percentage of node-blast infection at 10.1-15.0%and its neighbouring class-values based upon the calculation made on each individual with different number of tillers among which one and two were infected.

No. of infcet. tillers	Number of tillers per plant													
	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	%													
1	16.7	14.3	12 5	11.1	10.0	9.1	8.3	7.7	7.1	6.7	6.1	5.9	5.6	5.3
2	33.4	28.6	25.0	22.2	20.0	18.2	16.6	15.4	14.2	13.4	12.2	11.8	11.2	10.6

According to the above table, it is found that in the case of the reading where one tiller was infected, the class-value of 10.1-15.0% was obtained only from the series of the plants having 7, 8, or 9 tillers and in the other, i.e. infection of two tillers, the same was found in the plants with 14, 15, 16, 17, 18, or 19 tillers. On the other hand, all the members of the plants with 10-13 tillers revealed 5.1-10.0% and 5.1-20.0% in the 1-and 2-tiller infection, resp. Accordingly, the individuals having 10-13 tillers are excluded from the class-value of 10.1-15.0% in the present experiment. As a matter of fact, the reading was susually made on the plants with the tillers from 10 to 13, when one or two of them were infected; consequently, the frequency at the class-value 10.1-15.0% might be greatly lessened. Hence, the minimum point appeared at this class-value is considered to be due largely to such chance occurrence. By the same reason the occurrence of certain small minima found at the class-value other than the above-named can be explained, although in these cases the grade and frequency of occurrence were less than the above owing to less frequency of individuals of which more than two tillers were infected.

Lastly, mention is also made of the point that some of the segregates

were more susceptible than the ausceptible parent, but this fact may be interpreted in the same manner as stated in the neck-blast resistance. In view of the data mentioned above, it is almost beyond doubt that the parallelism of the curves in the different crossings between the resistant and susceptible varieties may indicate the presence of two main alleromorphic factors which govern the node-blast resistance.

(b) F_3 generation

(1) Leaf-blast resistance

Experiments on the seed-beds

On Sept. 27, 1947, upland seed-beds were prepared in four experimental plots encircled with concrete wall, each of which is 2.5 x 32.0 (m.) in area. Each plot was divided into two sections, 60 cm. and 120 cm. wide, resp, arranged parallel to the long side of the wall, and these were used for the control plot (Taichu No. 65 was planted.) and the test plots (for the parental and F_3 lines), respectively. The beds were manured with ammonium sulphate quadruple as much as the ordinary amount. The test plots were further divided into many line-plots of 45 x 25 (cm.) in area. The seeds to be tested were those of F_2 individuals which were used for the study of the neck- and node-blast resistance. All the seeds selected at random were sown in each plot, apporximately 300 seedlings being grown for each line. In considering the fact that the number of seeds of each line was naturally different according to the difference of number of ears per F_2 individual as well as number of kernels per ear of it, the grade of fertility due to the sexual affinity between the parents, and sterility caused by the blast infection during the F_2 generation, the utmost efforts were made to provide F_3 line with the uniform spacing of the seed-bed. For instance, in the case of very fertile lines no much surplus of seeds were used. On the other hand, in the case of about one-third of the lines of Kinoshita-mochi x Boera Ropo and in that of a small number of lines of Kinoshita-mochi x Malagkit Pirulutung, the F_3 individuals were not sufficient enough for the above-named area, so that these plots were narrowed to the proper area in order to keep the plants growing in uniform density. It was inevitable, however, in certain lines which were

very small in number of individuals the seedlings grew more or less vigorously due to plenty spacing, and were less liable to infection in comparison with those uniformly sown on account of less moisture of the air of the seedling-layer, notwithstanding that all the lines were carefully sprayed to render the infection drops uniformly remain on the plant surface. Accordingly, such lines had to be excluded from observation, though some errors might have been committed. The artificial inoculation were repeated until the susceptible lines were withered completely.

A heavy infection occurred in the F_3 lines of Kinoshita-mochi × Malagkit Pirulutung, some of which were completely destroyed about 40 days after sowing(vid. fig. 28, A), whereas in the other two crosses which were similarly bred by crossing between the resistant and susceptible varieties, i.e. Kinoshita-mochi × Davao and Kinoshita-mochi × Boera Ropo, infection was much slighter than the first-named. Such a difference of infection in the F_3 lines derived from the different crossings which was made with the same pistillate parent (Kinoshita-mochi) is considered due to the difference in the grade of resistance of the different male parents used in these crossings as shown by the following table representing the variation of severity of infection of them. In order to determine the mode of segregation, it was first intended to divide all the F_3 individuals of every line into certain classes of severity of infection, but this is very troublesome, and moreover it is somewhat questionable whether or not this method is able to express exactly the segregation of F_3 lines as a whole, since its severity of leaf-blast of the individual seedlings, especially under the outdoor condition, is much variable as already experienced. The segregation were therefore determined according to the severity of infection of a line as a whole. Reading of the severity was done by classifying the lines into 10-per cent classes based upon the approximate counting of number of the affected seedlings in each line.

Tablb 113. Distribution of the F_3 and parental lines into the percentage of the leaf-blast infection.

Parents & crosses	Number of lines in each infection - class											Total
	% 0	10	20	30	40	50	60	70	80	90	100	(Ratio)
Kinoshita - mochi									3	9		12
Malagkit Pirulutung	3	9	5									14
F_3	43	30	10	7	10	6	1	8	10	15	4	144
	(83)			(		24	)	(	37		)	(9:3:4)
Kinoshita - mochi									2	4	1	7
Davao	10											10
F_3	85	7	14	9								115
	(85)	(	30	)								(12:4)
Kinoshita - mochi										1	4	5
BoeraRopo	12	1										13
F_3	152	9	4	7	2							174
	(161)		(	13	)							(15:1)
Asse Banda	15											15
Hirayama	8	1										9
F_3	153	3										156

In the crossings between the resistant and susceptible varieties the F_3 lines showed the segregation-ratios of 9 :3 : 4, 12 : 4, and 15 : 1, all of which suggest the presencc of two dominant factors for leaf-blast resistance. In the crossing within the resistant varieties, i. e., Asse Banda x Hirayama, all the lines tested were quite free from infection except only three in which a small number of the seedling were slightly infected.

Expariment in the paddy field

During the course of the 2nd crop of 1947, 58 F_3 lines of Asse Banda x Kinoshita-mochi were selected at random and cultured in the paddy field in the similar multural manner as in the F_2 generation. As the number of F_3 plants in each line was naturally different according to the fertility of the F_2 plants, 20 to 280 individuals per line (amounting to 4811 individuals in all) were transplanted on Sept. 2. The repeated inoculation on the rainy days and installation of a windbreak during the monsoon season (Oct. - Dec.) rendered the infection heavier after the late tillering stage. Reading of the severity of leaf-blast infection of the individual plant was conducted on Dec. 9 by classifying the plants into the following six categories.

Class R. Resistant (Almost no lesion or a few lesions).

Class MR. Moderately resistant (Several lesions (5 - 10) per plant).

Class I. Intermediate (A considerable number of lesions, but all the leaves are still vivid.)

Class MS. Moderately susceptible (Some leaves are withered.)

Class S. Susceptible (About a half number of leaves are withered.).

Class HS. Highly susceptible (Almost withered.).

Class ES. Extremely susceptible (Completely wrotted.).

In the following table the hybrid lines employed in the present experiment are arranged on the basis of possible genetic constitution of the F_2 plants determind according to the data of segregation in the F_3 generation (*vide* also fig. 28, B, C & D).

Table 114. Segregation of leaf - blast resistance of F_3 lines derived from F_2 individuals of Asse Banda x Kinoshita - mochi, different in reaction to neck - blast.

Line no.	F_2 neck-blast (%)	Segregation of F_3 individuals								Possible ratio	Possible gen. const.
		R	MR	I	MS	S	HS	ES	Total		
A. Banda	0	44							44	All R	AABB
K. - mochi	62.5					2	36	4	42	All S	aabb
F_3 No.											
33	0	88							88	All R	AABB
35	10.0	76							76	Do.	Do.
45	0	86							86	Do.	Do.
114	0	80	2						82	Do.	Do.
6	0	65	19						84	3R : 1MR	AABb
174	20.0	26	13						39	Do	Do.
213	12.5	53	20						73	Do.	Do.
55	27.3	51	49						100	Do.?	Do.?
5	0	58	20	8					86	Do.?	Do.?
98	0	64	16	5					85	Do.	Do.
182	7.1	62	15	5					82	Do.	Do.
232	7.2	18	31	10					59	?	?
74	7.7	22	74	4					100	?	?
92	0	55	12	12	7				86	3R : 1MS	AaBB
93	0	51	13	15	7				86	Do.	Do.
61	0	56	3	20	3	2			84	Do.	Do.
241	0	34	45	6	18	2			105	Do.	Do.
315	6.7	12	18	3	5	4			42	Do.	Do.
3	0	167	64	35	3	9	1		279	9R : 6I : 1S	AaBb
30	0	37	11	15	11	4		5	83	Do.	Do.
36	10.0	116	20	36	19		4	2	197	Do.	Do.
64	20.0	11	149	42	8	6	4		220	12R : 3MG : 1S	Do.
87	20.0	10	20	3	6			3	42	Do.	Do.
43	0	7	14	15	7	14	24		81	9R : 7S	Do.
61	0	17	24	10	12	17	6		86	Do.	Do.
102	10.0	4	17	4	9	6			40	Do.	Do.

22	8.3	21	8	2		1	1		33	15R : 1S	Do.
123	0	53	17	4		1	4		79	Do.	Do.
40	0	5	77	18		4	1	1	106	Do.	Do.
68	42.9	24	93	19		2	5	1	144	Do.	Do.
78	90.0	5	28	3		1	1		38	Do.	Do.
86	25.0	6	16	3			1	1	27	Do.	Do.
107	11.1	9	21	6	1		2	1	40	Do.	Do.
161	0	17	110	14	1	5	4		151	Do.	Do.
189	8.1	12	41	7				2	62	Do.	Do.
228	0	16	59	8				3	86	Do.	Do.
73	7.2		13	8	1				22	All MR	AAbb
307	9.1		52	5	6				63	Do.	Do.
85	16.7		39	19	2	3			63	Do.	Do.
136	8.3		15	3		3			21	Do.?	Do.?
195	33.3		15	5		1			21	Do.?	Do.?
181	25.0		9	3	5	2	1		20	3MR : 1S	Aabb
24	6.7		67	37	7	25	7	4	147	Do.	Do.
39	25.0		37	35	12	18	2	1	105	Do.	Do.
18	0		18	30	29	20	9	2	108	Do.	Do.
23	57.1		10	21	17	9	4	2	63	Do.	Do.
82	10.0		8	23	24	9	15	4	83	Do.	Do.
90	0		30	49	28	15	2		124	Do.?	Do.
187	31.3				18	14	5	1	38	All MS	aaBB
293	33.3			1	4	8	5	1	19	Do.?	Do.?
16	30.0		4	6	12	18	9	13	62	3MS : 1S	aaBb
34	0		7	39	54	9	20	8	137	Do.	Do.
71	0			20	21	18	18	25	102	Do.	Do.
180	81.8			6	15	24	13	23	81	Do.	Do.
78	90.0				9	32	21	25	87	Do.	Do.
31	0					1	4	80	85	All S	aabb
271	66.7						6	81	87	Do.	Do.
309	91.7						2	84	86	Do.	Do.

Although there are several lines which are doubtful in their mode of segregation, the F_3 lines as a whole indicated the dihybrid mode of inheritance as shown by the following table by which x^2 for fit to a 9 : 3 : 3 : 1 ratio gave a value of P of 0.58.

Table 115. Number of F_3 lines of Asse Banda x Kinoshita-mochi classified by the leaf-blast segregation of F_3 individuals into each genetic constitution.

Genetic constitution	AABB	AABb	AaBB	AaBb	AAbb	Aabb	aaBB	aaBb	aabb	Total
Theoretical ratio	1	2	2	4	1	2	1	2	1	16
No. of lines observed	4	9	5	18	5	7	2	5	3	58
No. of lines calculated	3.6	7.2	7.2	14.5	3.6	7.2	3.6	7.2	3.6	58

As the susceptibility of the F_2 plants to the leaf-blast could not be satisfactorily graded because of the insufficient infection, the percentage of neck-blast infection of the F_2 generation was compared with the leaf-blast segregation of the F_3 individuals. So far as the present selections were concerned, the phenotypic resistance of the neck in the F2 generation was not necessarily parallel to the segregation of the leaf-blast resistance of F_3 generation, though a considerable number of the neck-susceptible F_2 lines showed the heterozygous- or homozygous susceptibility for leaf-blast in the F_3 generation. The presence or absence, or the grade, of such a parallelism of resistance of the different parts or organs of the plants is considered merely due to the characteristics of the varieties, and the inheritance of such characteristics was confirmed by the third serises of experiments which will be mentioned in the next paragraph.

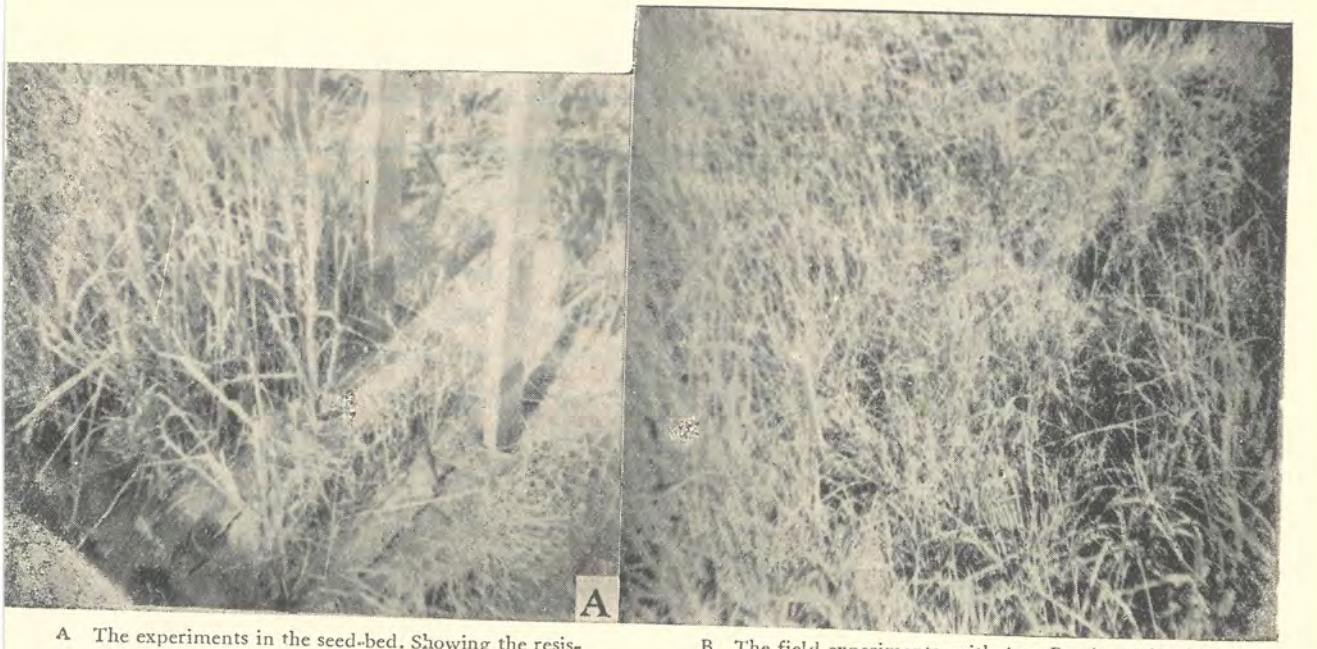
C. The Third Series of Experiments

(a) F_2 generation

(1) Leaf-blast resistance

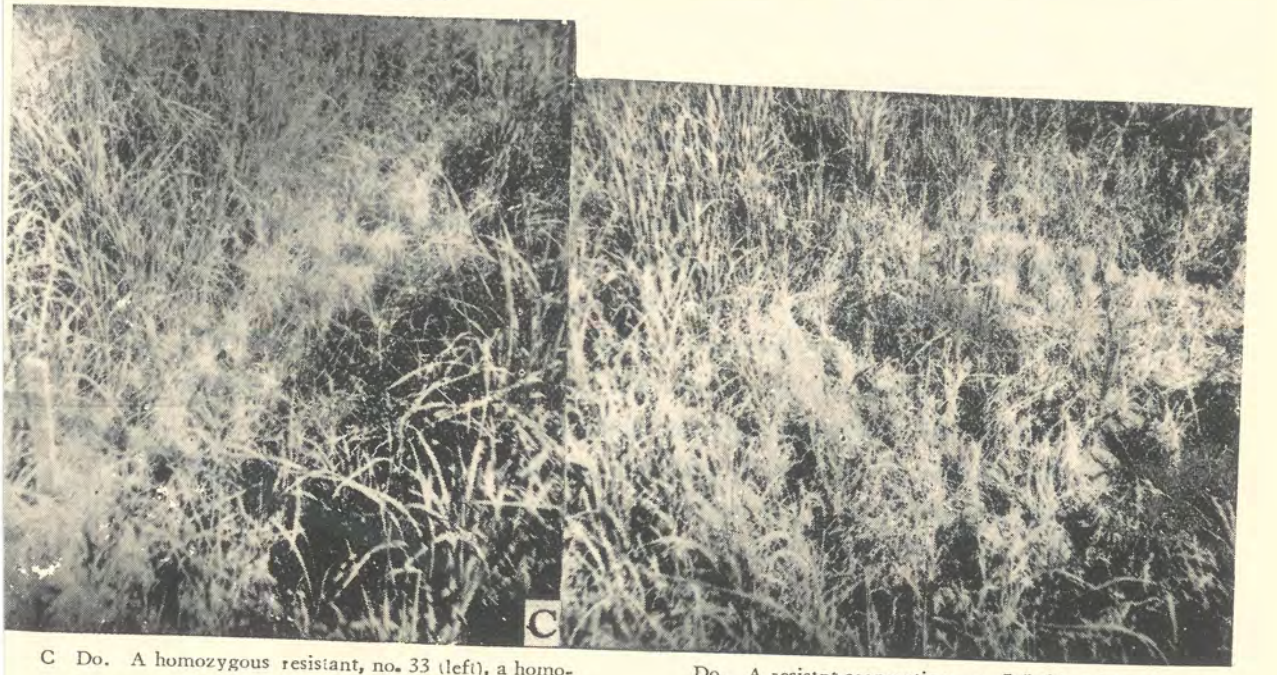
On Oct. 22, 1947, the seeds of the self-pollinated F1 plants were sown accompanied with those of their parent varieties in the wooden box of 50 x 35 x 15 (cm.) The seedlings were grown under a glass-house condition with excess of nitrogen (four times as much as the ordinary amount of ammonium sulphate) and inoculated (Nov. 7) when they attained the 4- or 5- leaf stage. Determination was made on Dec. 8 (*vide.* fig. 29, a) according to the following gradations.

1. Healthy (No lesion of almost none).
2. A few lesions.
3. A considerable number of lesions.
4. Heavily infected, though still survived.
5. Almost deceased, though still faintly greenish.
6. Completely withered.



A The experiments in the seed-bed. Showing the resistant lines (0%, left two), the highly susceptible line (90%, middle) and the completely susceptible line 100% of Kinoshita-mochi x Malagkit Pirulutung.

B The field experiments with Asse Banda x Kinoshita-mochi. Two homozygous resistant lines, no. 45(left) and no. 33 (right), and segregating line, no. 43 (middle).



C Do. A homozygous resistant, no. 33 (left), a homozygous susceptible, no. 31 (middle), and a segregating, no. 30 (right)

Do. A resistnt segregating, no. 5 (left). nd two homozygous susceptible, no. 309 middle and no. 271 (right).

Fig. 28. Leas.blast resistance of F_3 lines in the 2nd series of experiments on the inheritance of resistance.

Table 115. Reaction of the F_2 seedlings to the leaf-blast in the glass-house.

Parents & F_2	Number of plants with the reading of the grade 1	2	3	4	5	6	Total (Res. :Sus.)
Taichu No. 65				40	51	4	95
Blue Rose			21	76			97
F_2			54	76	105	30	265
N. C. No. 4			14	168	18		200
Komonawai	44	61					105
F_2	116	126	101	43	67	43	496 (343 : 153)
Taichu No. 65				16	48	4	68
Tobura		56	41				97
F_2	13	59	120	25	42	26	285 (217 : 68)
Tah-li-wan		76	12				88
Taichu No. 153			8	56	12		76
F_2	64	27	10	9	16	8	134 (101 : 33)
Tah-li-wan	2	58	36				96
Ching-sing-tzu		46	72	2			120
F_2	20	33	16	13			82
Pai-ku	79	61	9				149
Po-yang-tsao	3	30	16				49
F_2	69	58	35	2			164
Bali Atjeh	78	11					89
Peh-mi-fen	115	3					118
F_2	183	9					192

As shown by the above table, the F2 individuals of the crossing within the susceptible varieties, *i. e.*, Taichu No. 65 x Blue Rose, were all susceptible, badly affected with the formation of large, dark grey and abundantly sporulated lesions, while those within the resistant, *i. e.*, Tah-li-wan x Ching-sin-tzu, Paiku x Po-yang-tsao and Bali Atjeh x Peh-mi-fen, were all resistant bearing small brown lesions with meagre sporulation as observed in their parents. The ratio of segregation in the crosses between the susceptible varieties and the resistant, *i. e.*, N. C. No. 4 x Komonawai, Taichu No. 65 x Tobura and Tah-li-wan x Taichu No. 153, was assumed to be 3:1 or 12:4. Considering the fact that in two crosses, *i. e.*, N. C. No. 4 x Komonawai and Tah-li-wan x Taichu No. 153, the number of the highly resistant segregates exceeds that of the moderately resistant, the above-named segregation seems not to be conditioned by a single factor.

(2) Neck- and node-blast resistance

During the 2nd crop season in 1947, the F2 progenies were cultured parallel with their parent varieties in the paddy field under similar nutritional and soil moisture conditions as in those in the 2nd series of experiments. Although the outbreak of the leaf-blast was not sufficient enough for the determination of segregation, a proper infection of neck-and node-blast was secured in all the crossings except a crossing, Kisshin × Keta Boera. In the latter, many of the individuals were affected so heavily during the tillering stage that they could not develop normal ears. Among 231 plants employed, 83 were killed prior to heading, 128 out of 148 headed plants also died previous to maturity, and only 20 narrowly escape death and came to maturity (*vide.* fig. 29, B).

Owing to such a heavy infection, the mode of segregation, even that of the leaf-blast resistance, was hardly discernible. This was due to high susceptibility of both parents to leaf-blast. The male parent "Keta Boera" (introduced from Bima, Isl. Soembawa, Lesser Sundas) is one of the examples of the leaf-susceptible tropical varieties which are of rare occurrence, though the lesions are brown in colour due to the necrotic zone wider than that of the susceptible temperate varieties. The plants of the parental lines and the F_2 progenies except Kisshin × Keta Boera were pulled out when matured and classified according to the percentage of the neck- and node-blast infection in the similar manner as mentioned in the 2nd series of experiments. In the present series of experiments, a special attention was paid on the parts of plants attacked, *i. e.* the neck of ears and the node of culms. For this purpose, the following varieties were employed as parents, since they are different in their resistance according to the portions of plants.

Table 116. Resistance of the different portions of eaeh variety used in the third series of experiments.

Varieties	Leaves	Neck of ears	Node of culms
Kinugasa-wase	Suscept.	Mod. suscept.	Mod. suscept.
D 9	Suscept.	Resist.	Suscept.
Taichu No.65	Suscept.	Resist.	Resist.
Blue Rose	Mod. suscept.	Resist.	Suscept.
Tobura	Resist.	Resist.	Suscept.
N. C. No. 4	Mod. suscept.	Resist.	Mod. resist.
Komonawai	Resist.	Suscept.	Suscept.
Kinoshita-mochi	Suscept.	Suscept.	Mod. suscept.
Asse Banda	Resist.	Resist.	Resist.
Urazo	Resist.	Mod. resist.	Suscept.
Som Cau	Resist.	Mod. suscept.	Resist.
Aikoku No.1	Suscept.	Resist.	Mod. suscept.

By use of these varieties for hybridization, the mode of inheritance of resistance of the different plant-parts could be confirmed. The frequency distribution of the F2 individuals into the 5-per cent infection classes and the goodness of fit to the theoretical ratio will be shown by tables 118 and 119.

This is a neck-resistant line which wae selected by Shingchu Agr. Expt. Sta. Therefore, the reaction of this line to the neck- and node-blast is considerably different from that of the variety employed in the 2nd series of experiment under the same name.

As shown by the tables 117 and 118, the F_2 individuals of many of the crossings showed a segregation which is very close to the theoretical ratio of the dihybrid basis. Accordingly, there is almost no doubt that the neck - and node - blast resistance is governed by two alleromorphic factors. It is further to note that the blast resistance of the different parts of plants is inherited independently. For instance, in the case of node - blast infection the F_2 progenies derived from the crossing between Taichu No.65 and Blue Rose segregated in the ratio close to the theoretical, since the female parent was resistant and the male was susceptible to node - blast, while as for the neck --blast resistance they did not show a distinct segregaticn owing to the similarity of both parents in their resistance - susceptibility behaviour. The F_2 plants between Som Cau (susceptible to neck - blast but resistant to node) and Aikoku No.1 (resistant to neck - blast but susceptible to node) showed a distinct segregation for both neck - and node - blast resistance due to the distinct difference of resistance to both neck - and node - blast of both parents.

Table 117. Distribution of the parents and the F_2 individuals into the percentage of neck- and node-blast infection.

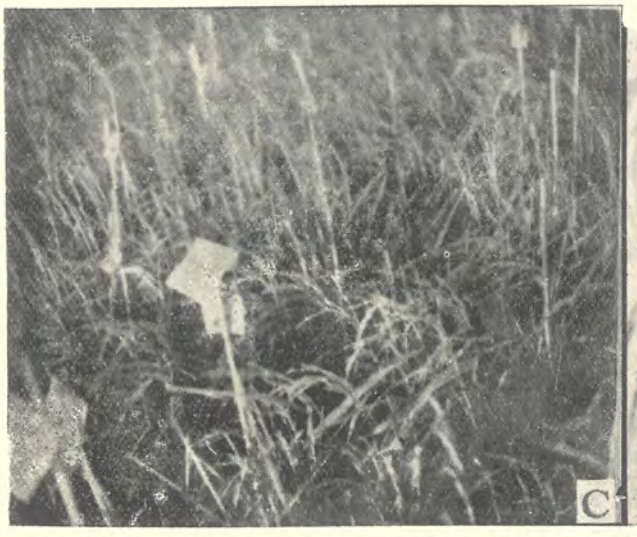
Parents & F_2	Parts of plants	Number of individuals in each class																					Total
		0%	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	
Kinugasa-wase	Neck										13	13	4										30
D 9	Neck	13	11	5	1																		30
Kinugasa-wase x D9	Neck	13	34	16	24	13	13	8	14	5	7	3	4	1	2	2	1	2	1	2			165
Taichu No. 65	Neck	5	13	9	3																		30
	Node	7	9	9	5																		30
Blue Rose	Neck	15	10	6	4														9	20	5	1	35
	Node																						35
Taichu No. 65 x Blue Rose	Neck	32	39	30	34	20	13	14	10	4													196
	Node	26	20	17	16	11	10	13	14	7	14	8	7	7	7	4			3	6	3	3	196
Tobura	Neck	18	10	7	1																		36
	Node																		1	3	17	15	36
Taichu No. 65 x Tobura	Neck	146	62	27	23	12	10	8	6	3													297
	Node	43	36	25	45	21	12	21	18	10	22	10	7	7	1	3	4	5	3	3	1		297
N. C. No.4	Neck	7	8	9	6																		30
	Node					7	10	13															30
Komonawai	Heading was quite irregular.																						
N. C. No.4 x Komonawai	Neck	47	28	20	26	8	4	8	7	7		1	2	1	2	1		1	2				165
	Node				5	9	10	11	11	18	11	12	10	5	15	12	13	11	6	1	5		165
Kinoshita-mochi	Node								2	2	4	8	3	2									21
Malagkit Sinoguing	Not headed.																						
Kinoshita-mochi x M. Sinoguing	Node	36	14	13	16	12	5	7	11	5	6	1	2	4	1	2							135
Som Cau	Neck								10	15	8		2										35
	Node	18	12	5																			35
Aikoku No.1	Neck	23	8	4																			35
	Node									10	15	9	1										35
Som Cau x Aikoku No.1	Neck	61	38	31	39	22	10	20	14	12	10	4	1	5	5	2	5	1					280
	Node	17	18	35	27	30	24	31	29	13	19	14	9	1	8	4	1						280
Asse Banda	Node	25	6	2																			33
Urazo	Node												8	14	9	3		1					35
Asse Banda x Urazo	Node	42	20	14	13	7	13	13	5	9	8	1	3	2	1	5	1	1	2				160

Table 118. Number of individuals grouped by the numerical distribution of neck-and node-blast infection and calculation of goodness of fit to a theoretical 9 : 3 : 3 : 1 ratio.

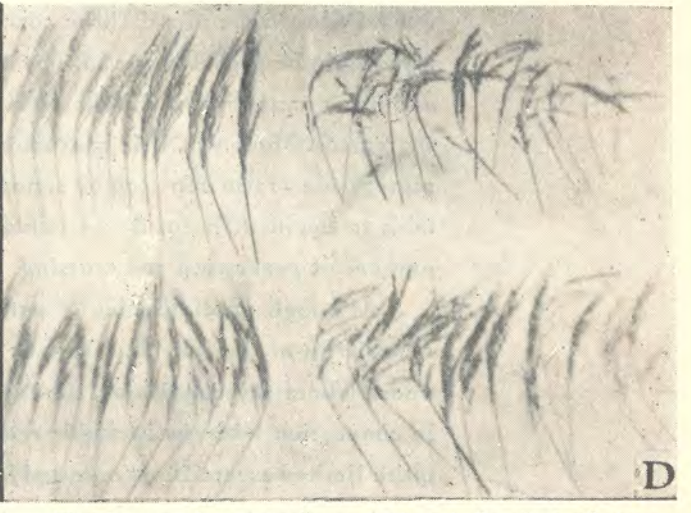
Crosses	Parts of plant	Grouping	Number of individual		$\frac{(O-C)^2}{C}$	x^2 & P
			Observed	Calculated		
Kinugasa-wase x D 9	Neck	Resist.	100	92.81	0.5569	x^2=4.2975 P =0.233
		Mod. res.	21	30.94	3.1934	
		Mod. sus.	33	30.94	0.5011	
		Suscept.	11	10.31	0.0461	
		Total	165			
Taichu No.'65 x Blue Rose	Node	Resist.	90	109.25	3.3919	x^2=8.2983 P =0.041
		Mod. re .	44	36.75	1.4303	
		Mod. sus.	47	36.75	2.8589	
		Suscept.	15	12.25	0.6173	
		Total	196			
Taichu No. 65 x Tobura	Node	Resist.	170	167.06	0.0517	x^2=0.4864 P =0.943
		Mod. res.	51	55.69	0.3935	
		Mod. sus.	57	55.69	0.0307	
		Suscept.	19	18.56	0.0105	
		Total	297			
NC No. 4 x Komonawai	Neck	Resist.	95	92.81	0.0516	x^2=1.1459 P =0.768
		Mod. res.	34	30.94	0.3027	
		Mod. sus.	26	30.94	0.7823	
		Suscept	10	10.31	0.0093	
		Total	165			
	Node	Resist.	97	92.81	0.1892	x^2=2.0559 P =0.563
		Mod. res.	32	30.94	0.0363	
		Mod. sus.	30	30.94	0.0286	
		Suscept.	6	10.31	1.8018	
		Total	165			
Kinoshita-mochi x Malagkit Pirulutung	Node	Resist.	63	75.94	2.2050	x^2=5.4367 P =0.146
		Mod. res.	33	25.31	2.3295	
		Mod. sus.	30	25.31	0.8650	
		Suscept.	9	8.44	0.0372	
		Total	135			
Som Cau x Aikoku No.1	Neck	Resist.	130	157.50	4.8016	x^2=12.1397 P = 0.007
		Mod. res.	61	52.50	1.3762	
		Mod. sus.	70	52.50	5.8333	
		Suscept.	19	17.50	0.1286	
		Total	280			
	Node	Resist.	151	157.60	0.2683	x^2=2.1588 P =0.544
		Mod. res.	60	52.50	1.0714	
		Mod. sus.	55	52.50	0.1191	
		Suscept.	14	17.50	0.7000	
		Total	280			
Asse Banda x Urazo	Node	Res.	89	90.00	0.1111	x^2=0.5444 P =0.892
		Mod. res.	33	30.00	0.3000	
		Mod. sus.	28	30.00	0.1333	
		Suscept.	10	10.00	0.0000	
		Total	160			

(A) Leaf-blast resistance of the F_2 seedlings in the glass-house. Left - Taichu No.65 x Tobura; right - Taichu No.65 x Blue Rose. Note the infection severer in the right than in the left.

(B) The F_2 plants at the early stage of maturity in the field. Left half - Kisshin x Keta Boera (Mostly withered). Right half-Garum BalayxMansaku(Normally growing). The two raws at the center are the parental lines used for the control (Left raw - Keta Boera, all withered; right raw - Garum Balay).



(C) The F_2 progenies of Som Cau x Aikcku No.1 in the field. Two individuals at the front are homozygous susceptible. Every plant was marked with a label tied with a split bamboo on which the pedigree number, the date of heading, etc. were recorded.



(D) The ears from a single parental and F_2 plant of Asse Banda x Kinoshita-mochi. Upper left-Asse Banda (All resistant); upper right-Kinoshita-mochi (Most of the ears are affected.); lower left - A resistant F_2; lower right - A moderately susceptible F_2.

Fig. 29. The third series of experiments on the inheritance of resistance

Considering these data, it is inferred that in certain varieties the varietal resistance may be different according to the difference of parts of plants, consequently, in such cases resistance of the particular portions or organs may be inherited independently from that of the others.

In consideration of various data heretofore mentioned, it seems likely that the inheritance of resistance of rice plants to the blast disease is governed by two dominant factors for resistance. It is not obvious, however, whether the difference in conclusion between Sasaki (*loc. cit.*) and the present author is ascribed to the difference in materials, *i. e.* rice - varieties and races of the fungus used by these workers, or it is due to the errorneous determination made by either of the two owing to the complexity of phenotypes as well as to the modification induced by certain environmental factors. As already experienced by Nakatomi (*loc. cit.*) and Kuwatsuka (*loc. cit.*), the mode of segregation of the leaf - blast resistance can not be determined so easily, especially at a seedling stage, since the phenotypic symptoms of leaf - blast are very variable even in the plants which carry the same genes. Ramiah & Ramaswami (*loc. cit.*) also attempted to find out the mode of inheritance of rice blast resistance, but failed to come to a definite conclusion. It is presumed that their failure might be probably due to the technical difficulty as mentioned above and not nccessarily to the complexity of the genetic constitution of the segregates. Moreover, it is considered probable that the variability in the segregation - ratio reported by some workers may be sometimes attributable to the insufficient data secured from the experiments with a limited number of generation and crossing.

Although specialization of parasitism as well as physiological characteristics of the rice blast fungus have been studied by many workers under laboratory conditions, the experimental data regarding such races in connection with the heritable resistance of the rice varieties have been quite limited except those reported by Sasaki (1922, 1923) from Shikoku, Japan. According to Sasaki, the heavy infection noticed on the five plants out of 766 F_2 individuals which were derived from the crossing between Tsurugi No. 160 (resistant) and Benkei No. 116 (resistant) might be due

to a race (race B) more virulent than the race (race A) against which the parental resistance was tested, since both parents were proved to be completely resistant to race A.※ Recently, Ryker & Chilton (1942) confirmed by their further studies on the inheritance of resistance of rice to *Cercospora oryzae* that the resistance to one race was closely linked with the susceptibility to the other, but this linkage was probably broken in some crossings. So for as the present experiments were concerned, however, the author could not find any evidence concerning the presence of the different races which were so different in pathogenicity as to change the segregation - ratio. It is not obvious whether this was due to the fact that the present experiments were conducted under the presence of a single race or allied races which are not so different in their virulence, or to the phenomenon that the rice blast fungus is not so highly specialized as cereal rusts, smuts, mildews, etc.

In consideration of the facts mentioned above, it is almost impossible that in the study of the inheritance of rice blast resistance one can draw a conclusion perfectly free from doubt, since the experiments can not be made under the ideal condition. It is considered, however, that the present author's experiments may be somewhat advanced in the following points.

(1) Crossing was made between the varieties which are mutually quite different in resistance, especially to leaf - blast. This lessened the difficulty of deciding the phenotypic symptom of leaf - blast which is quite variable.

(2) The segregation of the leaf - blast resistance, especially in F_3 generation, was confirmed on the adult plants, accompanied by the observation on the individual seedlings and the F_3 lines as a whole at the seedling stage.

(3) Studies were also made on the neck - and node - blast resistance which was not tried by the previous workers.

※It is still open to question, however, whether or not this infection was really resulted from the inoculation with a different race, since his inheritance studies (loc. cit.) were conducted independently on such races and his progeny test was carried out at the locality different from the first place where the crossing was made.

(4) The segregation in the field was determined without much disturbed by "escaping" phenomenon, since all the experiments were conducted under the temperature conditions suitable for the outbreak of the disease.

Up to the present time, the varietal resistance of the rice plants has not been fully taken into consideration by scientists as a cause of prevalence occurring in such a wide range of climatic regions extending from the temperate region to the tropical, since most of the studies on the prevalence have been made in Japan where the rice culture is mostly made with the varieties which are not much different in their grade of resistance. As a matter of fact, the epidemic of this disease is chiefly limited to the temperate Asia, including Japan, Korea, Manchuria, etc., and to some extent to North America and Europe, but was not ever reported from the tropical Asia with an exception of Formosa, notwithstanding the fact that the occurrence of the disease has been reported from almost all over the rice - growing regions in the world. This phenomenon is chiefly due to the difference of the inherent resistance of the varieties distributed in the different regions and partly due to the difference of the climate and the method of cultivation particularly the amount of fertilizers given. Such a phenomenon has already been pointed out by the present author (1943, *b*) basing upon his survey in the southern China where the blast disease tends to become prevalent since the "Horai" varieties (the Japanese lowland type) were introduced from Formosa. Moreover, as has already been mentioned in section. 4 of this chapter, the prevalence in the temperate and the subtemperate regions is effected by the change of resistance induced by temperature conditions, because in these regions not only the temperature during the rice - crop season varies to a great extent, but also the varieties cultured in the greater part of these regions are susceptible to the disease and sensitive to the temperature conditions. On the other hand, in the subtropical and tropical regions the temperature condition is almost uniform throughout the year, and the reaction of the native varieties to the disease and temperature is contrary to that of the varieties growing in the temperate and subtemperate regions, consequently such an epidemic as seen in the temperate region is hardly recognizable in the

tropics. Thus the varietal resistance has an important bearing upon the prevalence. Accordingly, the increase of the varietal resistance induced by hybridization with the tropical varieties is one of the most important means in controlling the prevalence. Recently, Peturson (1947) pointed out that the epidemic of the stem rust in western Canada has been greatly restricted by the introduction of the resistant varieties. The same may be true with the present disease when the highly resistant varieties are bred by the above - named method of crossing and distributed widely throughout these particular districts.

CHAPTER VII.

CONTROL OF THE PREVALENCE OF THE RICE BLAST DISEASE IN THE TROPICS

As stated in the preceding six chapters, the factors controlling the prevalence of the rice blast disease in the tropics have been clarified by the studies chiefly conducted under the laboratory as well as glass-house conditions. According to the evidences obtained from the present studies, the prevalence in the tropics is governed chiefly by the factors directly relating to the host plants in contradiction to the fact that in the temperate regions it is rather influenced by the conditions concerned in the parasite. In this chapter, the author will summarize the results of his field experiments carried out for the past decade on the eradication of the parasite, prevention of infection by means of spraging, and increase of resistance by chemical and genetical treatments.

Section 1. Disinfection for the Purpose of Killing Dormant Fungus

Many workers in the temperate regions, such as those in Sapporo (43°04'N) (Ito & Kuribayashi,1931; Ito,1935), Manchuria (Sasaki,1943), Yamagata (ca.38°15'N) (Kawai,1941), Nagano (ca.36°40'N) (Kuribayashi & Kawai,1932), etc. reported that the conidia or hyphae of the present fungus remaining dormant in the straws are mostly or completely killed by freezing during winter when they were kept under the outdoor condition, though they remained viable in the heaps. In the southern Japan, however, Hemmi (1933) and Ikata *et al.* (1938) in Kyoto (35°01'N) and Okayama (34°04'N), resp., proved that the fungus survives throughout winter in the open-air even in the free conidial form. Moreover, under the subtropical condition (Taipeh,25°02'N), Sueda (1928) confirmed that the dormant hyphae in the straws survive more than one year in the outdoor. According to the author's experiments which were made at

Taichung (24°09'N) with the use of the hyphae remaining dormant in the nodes of culms of the 2nd crop-plants, the resultant data are as follows:

In water,viable for 20 days
Under the ground, viable for 40 days
On the ground, viable for 4 months
In thr outer part of the piled straws, viable for 6 - 7 months
In the inner part of the piled straws, viable for 9 - 10 months
In the room, viable for 12 - 14 months

As stated above, in the temperate regions the primary outbreak may be almost prevented by treating the hyphae in the inner parts of the piled straws and those indoors, but in the subtemperate regions it seems very difficult, since the succession of the inocula may take place not only by means of the hyphae in the straws (even in the open-air), but also by air-born conidia. Under the subtropical environments, prevention of the primary outbreak is very difficult by the reason that the fungus is capable of overwintering even in the open-air. Accordingly, killing of the dormant fungus may not be so effective in the subtropics as in the case of the northern climatic condition of Japan.

A. Seed Disinfection

Judging from the results so far obtained in Formosa, disinfection of seeds is rather ineffective as a preventing means of prevalence in nature, since according to the author's field experiments extending over several years as well as of the results of the application conducted by farmers under compulsion from 1941 onwards almost no distinct effect has been noticed, though Sueda (1927) advocated the excellent effect of the seed disinfection by means of hot water treatment under the condition of the lst crop at Taipeh. The following is an example of the author's experiments.

Table 119. Percentage of natural infection of the seedlings derived from disinfected seeds sown in seed-beds during the Ist crop season, 1937.

Varieties employed	Control (Not disinfected)	Disinfected with	
		Formalin	Uspulun
Taichu Sp.No.6	91.5	94.6	88.9
Taichu No.65	79.6	75.9	80.7
Uh-rwan-tzu	11.4	7.9	10.8

Sown, Mar.5,1938; observed, Apr.10. 2.16 litre of seeds were sown per plot (0.1 a. in area), duplicated.

This experiment seems to show that under the subtropical conditions the wind-blown conidia which are newly produced on the living host or originated from the dormant fungus scattered in glasses are more effective as inocula than the dormant fungus in the seeds.

B. Treatment of Stubbles and Straws

In the northern part of Japan, there are a considerable number of evidences supporting the idea that the primary outbreak of the present disease is closely correlated with the dormant fungus in the straws of the preceding crop. In order to ascertain whether or not this is also true of the primary infection of the disease in the subtropic like Formosa, the seedlings were transplanted to the four paddy-fields, each of which was equivalent to 0.52 a. in area, and treated in the following manners previous to transplanting.

The plot 1 was filled with water at the depth of 10 cm. for 20 days previous to transplanting so as to keep the stubbles immersed in water during this length of time.

The plot 2 was irrigated one day before transplanting in the same manner as in the ordinary cultivation (control).

The plot 3 was similar to the plot 1, except that the straws obtained from the preceding crop were inserted by the bundle into the soil instead of the stubbles.

The plot 4 was also treated similarly, but the straws were piled up along the foot-path around the plot instead of immersing them into the soil.

The seeds used in the present experiment were disinfected with formalin. The dormant fungus in the stubbles in the plot 1 is thought to be killed, as has already been proved by Sueda (1927) and the present author. This experiment was repeated for several years, but in this place only the results of the lst crop in 1941 are tabulated, since the others were substantially the same as in this experiment.

Table 120. Ralation of the stubbles and straws remained in the paddy-field to the primary infection of the disease in the following year.

Plot no.	Date of primary outbreak	Severity of leaf-blast	Percentage of infection		Yield of grains (Kg. per ha.)
			Necks of ears	Nodes of culms	
1	Mar.21	Severe	34 7	37.9	850
2	Mar.18	Severe	38.7	32 0	890
3	Mar.18	Severe	24.7	22.9	980
4	Mar.18	Severe	51.0	40.9	960

The above-mentioned results show that removal or the special treatment of stubbles and straws may not be effective in the subtropical regions in contradiction to the fact that in the northern Japan it serves as an effective control measure.

Section 2. Prevention of Invasion of the Fungus into the Host Plants

A. Spraying of the Fungicides

Concerning the spraying of the fungicides as a means of controlling the rice blast disease in tropics, we have a rather poor knowledge. Sawada (1926) confirmed in Formosa that the copper soap solution has almost no effect upon the prevention of the disease. The author (Taichu A.E.S., 1937 - 1941) conducted some field experiments for five years at Taichung. The results of these experiments are summarized below.

(a) The experiments in 1937 and 1938

During the lst crop of 1937 and 1938, the field trials were carried out

by means of the following manners.

Varieties employed - Kameno - o (a Japanese lowland variety) and Taichu No.65.

Experimental plots - Each was 0.2 a. in area, duplicated.

Cultivation of the employed plants - The plants were cultivated in the ordinary manners except that fertilizers were given twice as much as the ordinary amount (N 82 Kg., P_2O_5 57 kg., K_2O 85.5 kg. per ha.).

Spraying - Bordeaux mixture of 3 - 9 formula (3 g. of copper sulphate, 9 g.- of stone lime, and 1,000 cc of water) with resin sticker (1/100 in volume) was sprayed by use of a compressed air sprayer in the seed-bed (3,000 l. per ha.) and the paddy - field (tillering stage, 4,500 l.; just before heading, 5,000 l. and just after blooming 5,000 l.).

The resultant data are shown in table 121. These results showed that the spraying of the bordeaux mixture was almost ineffective as a means of control of rhe disease of leaves and necks of ears, though it was somewhat efficacious for diminishing the infection of the nodes of culms.

Table 121. Results of the spraying experiments with 3 - 9 bordeaux mixture in the paddy-field.

Spraying	Varieties employed	Year	Severity of infection					Yield (per ha.)	
			Leaves		Necks(%)		Nodes(%)	Weight (Kg.)	Volume (l.)
			M.T.※	L.H.※	A.H.※	M.※	M.※		
Spraying	Kameno-o	1937	Heavy	Severe	61.9	79.5	31.8	995	1,910
		1938	Slight	Slight	21 5	19.7	43.6	3,856	7,585
		Aver.			41.7	49.6	37.7	2,426	4,748
	Taichu No. 65	1937	Heavy	Moderate	16.3	19.9	15.2	3,811	6,960
		1938	Slight	Slight	10.8	12.3	3.9	5,006	8,978
		Aver.			13.6	16.1	9.6	4,409	7,969
Non-Spraying	Kameno-o	1937	Heavy	Heavy	63.5	75.4	29.1	1,857	3,620
		1938	Slight	Slight	12.2	21.6	69.2	4,958	9,665
		Aver.			37.6	48.5	49.2	3,408	6,643
	Taichu No. 65	1937	Heavy	Moderate	13.9	16.3	19.6	4,450	8,130
		1938	Slight	Slight	24.0	13.1	13.9	5,221	9,280
		Aver.			19.0	12.2	16.8	4,836	8,705

※ M.T. - The stage of maximum tillering; L.H. - Late heading stage; A.H. - 10 days after heading; M. - Maturity.

(b) The experiments in 1939, 1940 and 1941

Spraying experiments were also performed every year in the lst crop of 1939, 1940 and 1941 in combination with the seed-disinfection. The procedures of these series of experiments were as follows:

Experimental plots -

(1) Spraying in combination with the formalin seed-disinfection

(2) Spraying in combination with the uspulun seed-disinfection

(3) Spraying, but no seed-disinfection

(4) Control (No spraying and no seed-disinfection)

Spraying - Bordeaux mixture of 4-8 formula with "bordeaux soap" (a resin sticker) was used except the experiments in 1941, in which case "lino" (an oil sticker) was used as a sticker. The plants were sprayed in the same manner as stated in the preceding experiments at the rate of 2,000 and 3,000 litre per ha. of the seed-beds and paddy field, respectively.

Seed-disinfection - Ito's method (1932)

So far as the disease of leaves is concerned, the results of the above experiments were almost similar to those of the precedings excepting those in 1941, in which experiment spraying was somewhat efficacious by use of the excellent sticker, "lino". In general, however, spraying was rather effective for the control of the disease of ears and nodes of culms than for that of leaves probably due to the difficulty of adhesion of the liquid to the leaves.

Judging from these experiments, under the subtropical conditions the effect of spraying of the fungicide is rather limited, probably due to washing off the fungicides by rain, the rapid development of new leaves, and a large number of the conidia of the causal fungus floating in the air.

Table 122. Results of the spraying experiments with bordeaux mixture in combination with seed-disinfection.

Item	Varieties employed	Year	Severity of infection					Yield of grains (Per ha.)	
			Leaves		Neck of ears (%)		Nodes of culms (%)	Weight (Kg.)	Volume (l)
			M.T.※	L.H.※	A.H.※	M.※	M.※		
Spraying & formalin disinfection	Kameno-o	1939	Slight	Slight	78.4	70.8	46.0	3,446	9,813
		1940	Slight	—	79.1	—	18.5	2,572	5,307
		1941	Slight	Slight	42.1	41.3	39.7	1,000	2,100
		Aver.			66.5	56.1	34.7	2,339	5,740
	Taichu No. 65	1939	Slight	Slight	70.2	68.0	23.8	4,171	10.663
		1940	Slight	—	31.2	—	7.6	3,861	7,177
		1941	Moder.	Moder.	39.1	68.3	29.8	1,775	3,480
		Aver.			46.8	68.2	20.4	3,269	7,107
Spraying & Uspulun disinfection	Kameno-o	1939	Slight	Slight	88.2	74.7	39.4	3,317	9,429
		1940	Slight	Slight	80.7	—	53.7	3,782	5,573
		1941	Slight	Slight	36.6	53.6	15.0	1,160	2,390
		Aver.			78.5	64.2	36.0	2,753	5,797
	Taichu No. 65	1939	Slight	Slight	66.3	63.9	30.4	4,500	11,518
		1940	Slight	—	25.2	—	8.7	3,880	7,221
		1941	Slight	Moder.	35.1	57.1	17.2	1,875	3,490
		Aver.			42.2	60.5	18.8	3,418	7,496
Spraying & non-disinfection	Kameno-o	1939	Slight	Slight	85.8	71.8	46.5	3,313	9,502
		1940	Slight	—	70.6	—	39.3	2,557	1,213
		1941	Slight	Slight	40.5	44.1	29.3	875	1,910
		Aver.			65.6	58.0	38.4	2,247	5,541
	Taichu No. 65	1939	Slight	Slight	65.1	59.3	31.8	4,563	11,817
		1940	Slight	—	18.3	—	6.8	3,820	6,977
		1941	Moder.	Moder.	51.4	56.4	31.9	1,675	3,420
		Aver.			44.9	57.9	23.5	3,353	7,405
Non-spraying & non-disinfection	Kameno-o	1939	Slight	Slight	91.0	83.9	56.6	4,167	8,923
		1940	Slight	—	73.0	—	53.8	2,427	4,977
		1941	Slight	Heavy	42.1	53.1	35.8	775	1,700
		Aver.			68.7	68.5	48.7	2,456	5,200
	Taichu No. 65	1939	Slight	Moder.	84.4	70.0	33.2	4,288	11,191
		1940	Slight	—	25.9	—	7.7	3,820	7,097
		1941	Moder.	Moder.	41.4	77.9	39.1	1,600	3,080
		Aver.			50.5	74.0	36.7	3,230	7,123

※ M.T.=The stage of maximum tillering; L.H.=Late heading stage; A.H.=10 days after heading; M.=Maturity. Observation was not made.

B. Removal of Water Drops from the Leaves

In order to confirm the effect of removal of water drops, i. e., dew, rain, guttation, etc. from the leaf - surface on the outbreak of the disease under field conditions, the experiments were preliminary performed in the first crop of 1943 and 1944 (Taichu A. E. S., 1945). In the calm weather the dew usually falls at dusk and remains on the leaves till early in the next morning, during which period the blast fungus can invade into the host, as far as the temperature condition is favourable for the growth of the fungus (*vide* chapt. II, section 2, and chapt. III, sect. I). Numerous infections, however, occur only just after the daybreak by the reason that the floating conidia in the air are numerous only from midnight to daybreak (*videc* hapt. II, section 2).The seedlings of three varieties, Taichu Sp. No. 6, Taichu No. 65 and Taichu No. 150, were transplanted duplicately to the paddy plots (62 a. in area, 1240 hills) which were applied with twice the quantity of the chemical fertilizer. Removal of dew drops from the leaves was accomplished at different intervals as shown in the following table by brushing them off with the use of a jute rope of 20 m. long, each end of which is held by a person on either side of the paddy-field and moved four times in contact with he upper part of the plants.

Talbe 123. The schedule of removal of dew drops from the leaf surface of the rice plants at the tillering stage.

Plot no.※	Time of treatment		Number of treatment	
	1943	1944	1943	1944
1	-	-	1	0
2	Apr.5 - Apr.30	Mar.25 - Apr.20	26	22
3	Apr.5 - Apr.20	Mar.25 - Apr.10	16	12
4	Apr.10 - Apr.25	Apr.10 - Apr.20	16	14
5	"	-	5	5

※ Plot 1 - Control (No treatment). Plot 2 - Treated throughout the prevalent period. Plot 3 - Treated during the incipient stage of prevalence. Plot 4 - Treated during the serious stage of prevalence. Plot 5 - Treated only in the dewy mornings.

The resultant data are not so clear - cut, except that in the plot which was treated in the middle period of the prevalence, the infection was somewhat slighter when the dew was brushed off more frequently. Such a phenomenon seems to be due to the following facts : Some of the conidia

have alrecdy invaded into the hest prior to the treatment; minute dew-drops can not be complctely removed from the leaf-surface by the above-named methods; in the fine weather the dew may fall again on the leaves shortly after the treatment, etc.

Section 3. Artificial Promotion of Host Resistance by Means of Chemical Agents

A rather considerable number of reports have already been published concerning the promotion of the blast resistance of the rice plants by application of chemicals other than fertilizers. Nozu & Yokogi (1925) made study on the effect of bordeaux mixture applied to the soil on the infection of the disease in question. Since then, many substances have also been tested, *viz.*, bordeaux mixtnre (Satoh, 1930), copper sulphate (Abe & Okamura, 1931; Hemmi & Abe, 1932; Hemmi, 1942), silicates(Kawashima, 1927; Ito & Hayashi, 1931; Miyake & Ikeda, 1932; Suzuki, 1935, 1937; Akimoto, 1939; Yoshii, 1941, etc.), iodine compounds (Tasugi & Yamada, 1934 - 1936), etc. The study has also been made in Formosa. According to Sawada (1935), silicates, quick lime and bordeaux mixture are effective for the repression of the outbreak of the disease when applied to the paddy field. It was also reported from the Agricultural Research Institute, Government of Formosa (1942) that lime-nitrogen, sodium silicate, ash of rice straws and copper sulphate proved to be effective for the control of the disease in the order named.

Since 1937, the author has made some investigations on the effects of various chemicals which are added to the nutrient solutions of the water culture conducted in the glass house or to the soil of the paddy field under natural conditions. In the present paper the auther will permit himslf only to report some of the more important experiments carried out in the field.

A. Experiments in the Seed - bed (Taichu A. E. S., 1942)

At the lst crop in 1941, the disinfected seeds (0.9 litre per plot, 3.3 m^2) were sown duplicately on the seed - beds, to which several kinds of chemicals to be used for the study had previously been added. The number of seedlings free from the disease was counted 22 days after sowing (June 2).

Table 124. Effect of the chemicals added to the soil of seed-beds upon the natural infection of the seedlings.

Chemicals given	Amount of chemicals (Kg. or l. per ha.)	Height of Seedlings(cm)	No. of seedlings free from infect. (per0.9m²)
Control	—	12.1	160
Slaked lime	100 Kg.	13.0	504
Do.	750 Kg.	13.0	511
Bordeaux mixture ※	4.500 l.	23.8	689
Do.	13,500 l.	11.5	747
Potassium jodide	0.6 Kg.	15.7	3.333

※ 8-3 formula

As seen in the above table, the use of chemicals, especially that of KI, is thought to be very effective.

B. Experiments in the paddy field (Taichu A.E.S. 1943 & 1945)

In the lst crop of 1942 and 1943, various chemicals mixed with the chemical fertilizers were added to the soil of the paddy field previous to transplanting or 15 days after transplanting. The paddy-field was divided into the following 16 plots in triplicate. Only the results in 1942 will be shown here.

Table 125. Effects of the chemicals added to the soil of the paddy-field upon the severity of the natural infection.

Chemicals added					Severity of infection					Yield (Kg. per ha.)
		Time of applicat.			Leaves		Ears(%)		Nodes(%)	
Name	Amount added at a time※	Seed bed	Just before transpl	15 days after transpl	Maximum till.	Late till.	10 days after heading	Maturity	Maturity	
Contraol	—	—	—	—	++	+	22.8	35.9	6.5	4,740
Pot. jodide	5	+	—	—	++	+	22.9	25.9	8.3	4,570
Do.	5	+	+	—	++	+	23.2	32.1	8.8	5,650
Do.	5	—	+	—	+	+	14.2	25.0	6.3	5,570
Do.	5	—	+	+	+	+	11.5	26.6	9.3	5,290
Co.sulph.	10	+	—	—	++	++	21.5	25.1	7.8	4,060
Do.	10	+	+	—	++	++	20.5	24.6	9.7	4,060
Do.	10	—	+	—	++	++	21.5	34.3	10.6	3,930
Do.	10	—	+	+	+++	+	21.7	23.9	7.6	3,830
Slak. Lime	100	+	—	—	++	++	17.3	29.4	8.7	4,050
Do.	100	+	+	—	+++	+	18.7	26.8	4.8	4,450
Do.	100	—	+	—	++	+	21.0	24.0	14.9	3,630
Do.	100	—	+	+	++	+	12.2	20.3	11.3	4,860
Co. sul. & Sl. Lime	10+20	+	+	—	++	+	17.7	22.7	14.3	4,800
Do.	10+20	—	+	—	+++	++	20.4	31.5	8.9	3,090
Do.	10+20	—	+	+	+++	++	23.3	28.2	9.4	3,810

※ Kg. per ha.

In the above experiments, the plants supplied with potassium jodide were less susceptible to the leaf blast than those added with any of the other chemicals or those of control. However, if this chemical was applied only at the seed-bed stage and not in the later stage after transplanting, this tendency was hardly recognizable. Some minute brown necrotic spots appeared on the leaves immediately after the application of KI, but these lesions disappeared with the lapse of time, and finally the plants in this plot exceeded the other in the vegetative growth as well as in the yield of grains as a result of least infection, though the time of heading and maturity was slightly delayed.

Judging from the results stated above, the use of chemicals in the soil may be applicable to the seed-beds intermediate crop in Formosa during which crop the blast disease is very prevalent, but as regards the application of it to the paddy field it is left for further studies.

Section 4. Promotion of the Varietal Resistence by Means of Crossing between the Temperate- and Tropical Varieties

Under the subtropical and tropical conditions, cultivation of the resistant varieties is considered to be more efficacious as a control measure then the methods mentioned in the foregoing paragraphs, *i.e.*, the eradication of the fungus, the artificial promotion of the host resistance by the chemical means, etc. Nevertheless, unless the highly resistant varieties are secured, even this method is not sufficient enough to stand against the epidemic induced by some unfavourable environmental conditions as well as by ample supply of fertilizer which is generally practiced in order to get good yield. Sawada *et al* (1927) found that in the epidemic of the disease occurred in the lst crop season of 1926 the variety "Nakamura" which was one of the excellent varieties and very extensevely raised in Formosa at that time yielded not so much as some other resistant Japanese varieties simply because of the lower resistance to the neck-blast. Such a phenomenon has also been noticed by the author in various experiments on the varietal resistance. Accordingly, in order to meet the

requirement, the varieties to be grown in tropics should be excluded from the defects, such as the susceptibility of the "Horai" varieties as well as the poor quality and yield of the tropical ones. The author considers that such varieties may be produced by introducing the genes of the good yield and the high quality of the former and those of the high resistance of the latter. From this point of view, the author compared the resistance and yield of the lines selected by the author among the descendants derived from the crossing within the "Horai" varieties as well as those resulted from the hybridization between the above-named two different variety-groups, *i. e.* the "Horai" and the tropical, and further confirmed the differences in the above-named characters existing between the cross-bred varieties already completed in certain experiment stations in this island by the above-mentioned two different methods.

A. Resistance of the Selected Lines

A large number of crossing were made in the lst-and the 2nd crop of 1943, and the resistant and fertile lines were selected from the populations in every generation. In the lst crop, 1947, the selected lines of F_6 and F_7 were planted in the paddy fields fertilized with the normal- and triple amount of nitrogen, 200 individuals being used in each plot duplicately. The experimental plots were often cut from water supply so as to reduce the resistance of the plants, and the field inoculations were carried out several times at the tillering stage.

Although most of the lines, especially those of the F_7 generation, seemed to be pure, a few of them were still mixed with a small number of genes carried by heterozygous plants which were phenotypically evidenced. These heterozygous individuals were discarded and not used for the further studies. As shown in the above table, in general, leaf-blast resistance was higher in the lines resulted from the crossing between the different variety-groups than in those within the "Horai" group, though this tendency was not always remarkable in case of normal nitrogen supply. As to the neck-blast resistance, the same tendency was also recognizable, but in some lines resulted from the crossing between the different groups

Table 126. Resistance and yield of the selected pedigrees derived from the crossing within "Horai" varieties and that between the "Horai" and tropical under different nitrogen supply.

Grosses	Generation	N supply	Leaf blast ※	Neck blast ※※	No. of normal grains per ear	Sterility (%)	Yield (Kg. Per ha.)	Date of heading
Within "Horai"								
Taichu No. 65		N	+++	8.6	95.2	8.6	5,230	6.26
(Control)		3N	++++	30.6			2,890	
Taihoku No. 141 x	F_7	N	±	7.1	94.6	25.0	5,680	6.22
Taichu No. 150		3N	++	11.2			5,430	
Taihoku No. 141 x	F_7	N	+	3.1	71.2	17.7	4,440	6.20
Kanan No. S		3N	+++	24.8			2,930	
Taihoku No. 141 x	F_7	N	+	3.2	68.0	21.5	5,920	6.18
Taino No. 38		3N	+++	25.6			3,840	
Taihoku No. 141 x	F_7	N	++	3.5	85.6	10.6	6,080	6.20
Takao No. 12		3N	+++	7.8			5,690	
Takao No. 18 x	F_6	N	+	4.0	91.2	14.4	4,620	6.21
Taichu No. 150 (A)		3N	++	14.1			3,890	
Takao No. 18 x	F_6	N	+	10.6	86.6	9.7	3,905	6.21
Taichu No. 150 (B)		3N	++	36.0			2,480	
Taichu No. 150 x	F_6	N	+	5.2	93.8	8.4	6,076	6.19
Taino No. 45		3N	++	25.0			4,320	
Between tropical and "Horai"								
Balid x	F_6	N	±	0.6	146.2	24.0	4,350	6.24
Kanan No. 2 (A)		3N	+	5.0			4,410	
Balid x	F_6	N	+	4.9	114.2	39.1	3,850	7.03
Kanan No. 2 (B)		3N	++	18.6			3,110	
Balid x	F_6	N	−	2.2	94.0	37.5	5,000	7.02
Kanan No. 2 (C)		3N	+	2.6			5,140	
Balid x	F_6	N	+	10.3	106.6	10.5	2,770	7.02
Kanan No. 2 (D)		3N	+	38.7			1,760	
Cariniosa x	F_6	N	+	2.4	85.4	29.1	4,050	6.25
Shinriki		3N	++	10.6			3,650	
Davao x	F_6	N	±	0.8	9.6	29.1	4,430	6.29
Taihoku No. 8 (A)		3N	+	5.2			4,030	
Davao x	F_6	N	±	0.4	70.6	33.3	3,530	7.05
Taihoku No. 8 (B)		3N	±	0.4			3,070	
Elon Elon Pula x	F_6	N	±	2.6	70.8	18.6	3,670	6.19
Aikoku		3N	+	9.0			3,786	
Seri Mahi x	F_6	N	+	6.5	72.0	14.9	3,260	6.19
Taichu No. 65		3N	++	19.0			2,880	

※ Tillering stage (Apr. 30). ※※ Maturity.

The lineage of the "Horai" parents used in this study are as follows;

Taihoku No. 8—(Kyo-nishiki x Osaka-asahi) x (Meiji-ho x Yokichi-sen).

Taihoku No. 141—Taichu No. 65 (Kameji x Shinriki) x Chung-kou-gun.

Taino No. 38—Taichu No. 65 x Iwata-asahi.

Taino No. 45—Taino No. 16 (Shimebari x Kagi-ban No. 2) x Taichu No. 65.

Taichu No. 150—Taichu No. 65 x NC No, 4(Unknown Italian x Unknown Japanese).

Kkanan No. 2 & No.8—Uh-rwan-tzu x (Shinriki x Aikoku).

Takao No. 18—(Kairyo-aikoku x (Takenari x Kidai-nakate No. 76)) x (Taichu No. 65 x NC No.4)

All the tropical varieties used in this experiment are those native to philippines, except "Seri Mahi" which is native to Java.

susceptibility is as same as or higher than that of the hybrids derived from the crossing within the "Horai" varieties. This fact is considered to be chiefly due to the introduction of the resistant gene carried by certain lines derived from the crossing within such "Horai" varieties as those already bred by employing the resistant tropical varieties as one of their parents. For example, Taihoku No.141 was resulted from the crossing between Taichu No.65 and a Formosan endemic variety, Chun-kou-gun. It is also to note in this connection that certain tropical varieties employed in the presents experiments are considerably susceptible to neck-blast, though they are quite resistant to leaf-blast, consequently, the susceptibility revealed by some hybrids mentioned above might be partly due to this inherent character. In all the cases, however, it is evident that the resistance of all the lines is higher than that of Taichu No.65 which was bred by the crossing within the Japanese native varieties. The yield of grains was rather variable as the lines differ, but under the normal condition, so far as nitrogen supply is concerned, most of the lines derived from the hybridization within the "Horai" group yielded better than those resulted from the different variety-groups. This might be chiefly due to the higher sterility of the latter. On the other hand, in case of an excessive nitrogen supply, this tendency was often contradicted because of the inceased susceptibility of the former. The experiments were also carried out from the view point of other characters, such as fertility, awnless, growth habits suitable for the economic rotation-system in this island, etc., but in most of the cases studied the latter proved less fertile as mentioned above. Nevertheless, the author considers that this shortcoming might be overcome by further crossing of some fertile "Horai" varieties with those descendants.

B. Resistance of the Cross-bred Varieties

In this experiment, the resistance of the cross-bred varieties secured from the crossing within the Japanese endemic varieties or within the "Horai" varieties was compared with that of the varieties resulted from the hybridization between the "Horai" and the Formosan native varieties.

Table 127. Resistance and yield of the cross-bred varities derived from the hybridization within the "Horai" varieties and those between the "Horai" and the tropical under triple nitrogen supply.

Varieties employed		Leaf-blast		Neck-blast (%)		Yield
Name	Lineage	1947	1948	1947	1948	1948
						kg. / ha.
Crossed within Horai						
Taino No.34	Asahi x Kairyo-aikoku	+++	+++	14.3	37.1	3,000
Taino No.38	Taichu No.65. x Iwata-asahi	+++	+++	18.6	21.6	2,997
Taino No.46	Sakai-kaneko x Taichu No.65	+++	++	19.6	37.9	3,069
Taino No.50	(Sensho x Taichu No.65) x Takenari	+++	+++	9.9	11.3	4,066
Taino No.52	(Asaga x Taichu No.65) x Taino No.34	+++	++	10.1	14.1	3,126
Shinchiku No.4	Taino No.16(Shimebari x Kagiban No.2) x Taichu No.65	+++	++	21.6	41.9	3,388
Taichu No.65	Kameji x Shinriki	++++	+++	26.5	88.4	3,001
Taichu No.150	NC No.4(Italian x Japanese) x Taichu No.65	+	+	8.6	5.0	3,097
Taichu No.153	Taichu No.116(Taichu No.65 x NC No. 4) x Taichu No.114((Miyako x U-tzen) x Taichu Sp. No.6)) x Taichu No.65	+	++	11.6	6.2	3,049
Kanan No.11	((uh-rwan-tzu x Mitsui) x (Shinirki x Aikoku) x Taichu No.65	++	++	19.2	16.8	3,587
Kanan No.13	Do.	++	+	10.3	14.1	2,081
Crosse between Horai and tropical						
Taihoku No.105	Hunyea-ko-zu x Taichu No.65	±	+	17.3	2.9	3,969
Taihoku No.106	Taichu No.65 x Sha-chen	±	++	10.0	1.2	3,823
Taihoku No.108	Taichu No.65 x Chung-kou-gun	+	±	8.6	3.8	2,952
Taihoku No.110	Taichu No.65 x Ta-ko-tzun	+	±	20.6	9.6	2.966
Taihoku No.113	Hwa-tzun x Asahi	±	±	14.9	5.9	2,517
Taihoku No.121	Chung-kou-gun x Asahi	++	±	19.6	8.7	3,160
Taihoku No.125	Taichu No.65 x Paiku	+	+	13.6	3.3	2,839
Taihoku No.130	Taichu No.65 x Chung-kou-gun	±	+	5.6	2.2	3,010
Taihoku No.137	Taichu No.65 x Can-zu	+	±	4.4	1.4	2,710
Taihoku No.145	Taichu No.65 x Chung-kou gun	±	+	9.2	5.3	3,483
Taihoku No.177	Hwa-tzun x Asahi	++	+	8.2	6.9	2,694
Taihoku No.180	Asahi x Pai-bi-chen-kow	±	−	9.0	4.8	2,869
Taihoku No.190	Eumyea-ko-zu x Taichu No.65	+	+	4.4	3.1	3,049
Taihoku No.196	Taichu No. 65 x Ta-ko-tzun	+	±	10.7	7.6	4,840
Taihokn No.179	Asahi x Chung-kon-gun	±	++	8.3	6.8	4,126

The former were bred in the central and prefectural agricultural experiment stations in this island, amounting to eleven in all, and the latter were derived from the crossing made between the "Horai" and the Formosan native vatieties. All the varieties of the latter were bred at Taihoku (Taipeh) prefectural Agricultural Experiment station during 1930-1936 under the direction of S. Fujimoto, who conducted this breeding work for the purpose of improving the quality of the Formosan native rice. The experiments were conducted during the 2nd- and lst crop of 1947 and 1948, resp., in the similar manner as in the foregoing experiments except the nitrogen supply which was triple the amount of the ordinary manuring.

As seen in the table 127, many of the varieties derived from the crossing between the different types proved more resistant to this disease, especially to leaf-blast, than those within the "Horai" type. However, certain varieties of the latter, such as Taichu No.150, Taichu No.153, were also resistant in almost the same manner as the former. This result may be explained by the reason that these verieties were derived from the crossing within the "Horai" varieties, but one of the parents of the lateer had already been hybridided with the European or Formosan native varieties.

In view of the evidences mentioned above, the breeding of the resistant varieties by introducing the resistant genes of the tropical varieties into the "Horai" varieties is considered to be quite efficacious as a control measure of this disease, and, at the same time, this may also help to improve various other characters of the tropical rice-crop.

CHAPTER VIII.

DISCUSSION AND CONCLUSION

Although there are a considerable number of reports on the mechanism of prevalence of the plant diseases, most of them are discussed chiefly based upon the empirical observation or the statistical survey in the field, and the experimental studies on this matter have been rather limited. Kuderling (1936) pointed out that the field resistance of the wheat varieties to *Puccinia glnmarum tritici* is resulted from the complex of the temperature factor and the age of the varieties concerned. He therefore divided the wheat varieties into the following three groups according to the temperature relation, *i e.*, the varieties which are susceptible in the cool weather, those susceptible at high temperature, and those unchanged at any temperatures, and further into two groups according to the relation of ages to the rust resistance *i. e.*, the one which is susceptible when young but resistant at the adult stage, and the other which is irresponsive to age. Straib (1938) also reported that the summer resistance of the wheat plants to the yellow rust is due to the warm weather condition and the age of the host. As to the rice blast disease, Kuribayashi & Ichikawa (1941), studying the prevalence of the disease in Japan, recognized the following three distinct types, *i. e.*, the northern type, the middle type and the southern type. In the first type the prevalence is chiefly restricted to the reproductive stage of the plant, because in the earlier stage the parasite is unable to grow actively on account of coolness, in the last-named the disease occurs continuonsly throughout the whole period of rice-crop owing to the favourable temperature condition for the fungus growth, and in the middle type the mode of prevalence is determined by the weaather condition of the respective year, namely, getting close to either the northern type or the southern according to the temperature condition. In 1943, the author pointed out that the epidemic of the present disease in the subtropical monsoon regions, including Formosa, South China and

Hainan, is almost limited to the tillering- and maturity stage of the 1st crop, although as regards the mechanism of such a mode of prevalence a discussion has not been extensively mode.

A. The Types of Prevalence

In this paper, the author discussed the local and seasonal differences in the mode of prevalence extending over the different latitudinal regions in Eastern Asia, and analysed the factors constituting the prevalence by means of the experimental testimony, and lastly interpreted the mechanism of prevalence in the tropic based upon these evidences. According to the author's opinion (1943, *et* 1947), the prevalence of the present disease in Eastern Asia is divided into the four types, *i. e.*, the temperature type, the subtemperate type, the subtropical type and tropical type in accordance with the following characteristics (*vide* table 128).

B. The Factors Controlling the Prevalence

Among many actors which are presumed to be more or less related to the prevalence of the present disease, the following four factors as already stated in the respective chapters are considered to be of more importance as disease inducing agents. For convenience' sake, these will be briefly reviewed again as follows:

Factor a. Relation of Temperature to the Growth of the Blast Fungus (*vide* chapt. III) The temperature range for the growth of the blast fungus lies between 7 - 34° C, almost similar to that of the rice plants, but the vigorous growth of the fungus(*e. g.*, elongation of mycelia, germination of conidia, etc.) takes place only at 15 - 32°C, moreover, the active propagation and invasion of the fungus are at about 20 - 30°C. Accordingly, the epidemic does not occur naturally at any temperatures other than the range of the last-named, although the infection is often noticed even at the ranges of 15 - 20° C and 30 - 32° C. Thus the relation of temperature to the growth of the fungus is the primary important point to be considered in connection with the prevalence of the disease. The outbreak of the disease in any of the rice-crop regions except the tropics where the

Table 128. Characteristics of the four types of prevalence.

Characteristics	Temperate	Subtemperate	Subtropical	Tropical
Latitudinal range of prevalence	Ca. 36 - 44°N	Ca. 28-36°N	Ca. 15-28°N	Ca. 15N-25°S
Range of annual fluctuation of temperature (°C)	Ca. -5 -20	1 - 5 - 25	15-20-27-28	24-28
Mode of annual fluctuation of temperature	Sharp pyramidal	Pyramidal	Orowned	Lenear or wavy
Annual average of temperature (°C)	Ca. 10	Ca. 15	Ca. 23	Ca. 25
Annual isothermal line(°C)	5 - 10	10 - 20	20-25	25
Number of crop per year	1	1	2	1-3
Culturable period (months)	Ca. 6	Ca. 7	Almost 12	12
The ratio of duration of prevalence to possible durat of fungous growth	Prevalent durat =Durat. of fung. growth	Prev. durat. <Durat. of fung. grow	Prev. durat. <Durat. of fung. growth	Prev. durat. <Durat. of fung. growth
Prevalent season	Midsummer	Early summer	Spring	Whole year
Age of plants infected in nature	Heading-maturity	Seedling - tiller.(Head. -matur.)	Tiller. -mat. of the 1st crop	Seedling-tiller. (Head. -matur.)
Plant parts heavily infected in nature	Ears & nodes of culms	Leaves (ears & nodes)	Leaves, ears, & nodes	Ears & nodes (leaves)
Grade of prevalences	Severe	Moderate	Moderate - slight	Slight
Overwintering of mycelia in outdoor	Impossible (Possible only inside the piled straws)	Possible	Possible	Possible
Overwintering of conidia in outdoor	Impossible	Possible	Possible	Possible
Overwintering of fungus on living leaves	Impossible	Impossible	Almost Possible	Possible
Resistance of the endemic varieties	Susceptible	Susceptible	Resistant Susceptible	Resistant

temperature is always suitable for the prevalence throughout the year, is primarily controlled by the temperature factor, especially it is very evident in the high latitudinal regions, where the disease occurs only in the mid-summer on account of coolness.

Factor b. Relation of Temperature to the Resistance of Rice Plants (*vide*. chapt. IV). The resistance of the rice plants is increased in proportion to the increase of temperature of air and soil where the plants are grown, although this tendency become indistinct as the temperatures rise up to the point higher than the optimum for plant growth. The temperature also concerns itself in the so-called "disease escaping" by effecting the length of the growth duration of plants. The rice crop in the higher latitudinal regions is apt to be diseased because of the cool weather, likewise the 1st crop in the subtropical regions is also involved in epidemic on account of increase of susceptibility due to the low temperature which is lower than that of the rice-crop season in the subtemperature regions. On the other hand, the 2nd crop in the subtropics is not much suffered from the disease owing to warmness.

Factor c. Relation of Age of Rice Plants to the Resistance (*vide* chapt. V) It was evidenced by the author's experiments that the leaves of the rice plants are susceptible during the seedling and tillering stages except the very young seedling stage in which the leaves are quite free from the disease, then they become resistant at the late tillering stage and are further increased in resistance during the reproductive stage. The resistance of the necks of ears is also enhanced in proportion to the length of time after heading. This fact has an important meaning upon the prevalence, since the epidemic does not occur even in the weather favourable for the parasite, so long as the rice plants maintain resistance. It is explained, by the reason that the time of prevalence in the lower latitudinal regions (south of the subtemperate) is restricted to a rather short period notwithstanding the fact that the temperature condition for the parasite is favourable almost throughout the year. This phenomenon is more evidently shown in the tropics, where the temperature condition is favourable for the parasite as well as for the host all the year round, nevertheless, the

disease is prevalent only in the susceptible stage of the plants concerned.

Factor d. The Inherent Resistance of the Rice Plants (*vide* chapt. VI) Although the problem of inherent resistance of the rice varieties to the blast disease has been investigated by many workers, especially by those in Japan, no much attention has been paid upon the point that the inherent resistance may serve as a controlling factor of prevalence in different localities extending over such a wide range of climatic regions, *i. e.*, the tem perature region and the tropical, since most of the above-named workers have limited their study chiefly to the Japanese varieties which are not much different in the grade of varietal resistance. In considering the fact that there exists a great difference in resistance between the temperate varieties and the tropical ones as mentioned in particular in chapter VI, it is of no doubt that this is also important as a controlling factor of prevalence. This idea may be affirmed by the fact that the epidemic is resulted in Formosa and certain other districts of southern Asia from introducing Japanese lowland varicties or "Horai" varieties.

C. The Mechanism of Prevalence

The outbreak of the disease in different latitudinal regions is due to a single factor or the complex of the factors as shown by the following table.

Table 129. Controlling factors in relatiou to the prevalence of the blast disease in different latitudinal regions.

Types of prevalence	Controlling factors			
	a ※	b ※	c ※	d ※
Temperate type	+	−	−	−
Subtemperate type	+	−	+	−
Subtropical type	+	+	+	+
Tropical type	−	−	+	+

※Denoting the respective factor mentioned in the text.

The particulars on the construction of the respective type of prevalence will be mentioned as follows:

(1) The Temperate Type

The prevalence of this type is serious owing to the inherent susceptibility of the cultivated varieties and decrease of resistance due to coolness prevailling almost throughout the whole rice-crop season, notwithstanding the fact that the temperature during the prevalent season is ca. 20° C which is lower than the optimum for the growth of the fungus. In general, the prevalence occurs only during the stages of heading and maturity, since the temperature condition is unfavourable, being lower than the above-named during the vegetative stages of the plant. That is to say, in this type the disease breaks out only under the temperature condition which is suitable for the growth of the fungus, accordingly the prevalence period coincides with the warmest season of the year. This type of prevalence is noticed in the high latitudinal regions (36 - 44° N), including northern Japan, Manchuria, Northern China, etc.

(2) The Subtemperate Type

This type is also in intimate relation to the inherent susceptibility of the endemic varieties (the temperate or "Japonica" type) except in some part of Middle China where the resistant varieties (the tropical or "Indica" type) are raised. The prevalence occurs chiefly during the stages of tillering (leaf-blast), heading, and maturity (neck- and node-blast), though the temperature condition is favourable for the parasite throughout the growing period of the rice-crop except the seedling stage. The epidemic of leaf-blast is weakened after the maximum tillering stage because of the increase of resistance of leaves. In the southern parts of the subtemperate regions, however, the disease is prevalent even in the seed-beds owing to the favourable temperature. In this type, the infection of ears is somewhat slighter than in the temperate type, since the ears become more resistant than in the above-named type on account of warmness during this season. This type occurs in the main rice-crop regions in the temperate zone, including southern Japan, Middle China, etc.

(3) The Subtropical Type

In most of the subtropical region the native varieties (the so - called "Indica" type) which are highly resistant, especially to the leaf - blast, are raised. Accordingly, the prevalence in the subtropical regions is controlled in the first place by the inherent resistance of the cultivated varieties. Nevertheless, the prevalence in the limited localities, such as the Major part of Formosa and a part of South China as well as certain islands in tropical Asia, is characterized by the susceptibility of the cultivated varieties belonging to "Horai" type which have been distributed in the recent year. On the other hand, the prevalence is limited only to the period of the tillering and maturity stage of the crop notwithstanding the temperature condition favourable for the parasite as well as for the host almost throughout the year. This phenomenon is attributable to the complex of the temperature factor and to the host susceptibility due to age. That is to say, the prevalence does not occur during the seed - bed stage of the first crop (winter) on account of coldness which is unfavourable for the fungus, likewise it is greatly reduced during the vegetative stage of the 2nd crop (summer) owing to hotness, because in such a circumstance the rice plants become resistant and the fungus dose not grow well. Moreover, the plant - age of both crops has an intimate relation to the prevalence of the disease. Accordingly the prevalence is restricted to the short period as mentioned above, during which the susceptibility of the rice plants is compatible with the favourable fungus growth. Such relations are shown in fig. 30. This type is represented in the susbtropical monsoon regions, including South China, Formosa, Hainan, etc.

(4) The Tropical Type

In the tropical type the temperature condition for the rice - crop is rather lower than the highest temperature in the 2nd crop of the subtropical type and very suitable for the growth of both the parasite and host all the year round. The relation of temperature to the resistance of the rice plants as well as the growth of the blast fungus is almost invariable throughout the year. Accordingly, the prevalence is controlled by only the resistance due to age - difference. Moreover, the varietal resistance of the endemic varieties (the tropical or "Indian" type) is also responsible for the

restriction of prevalence to a great extent.

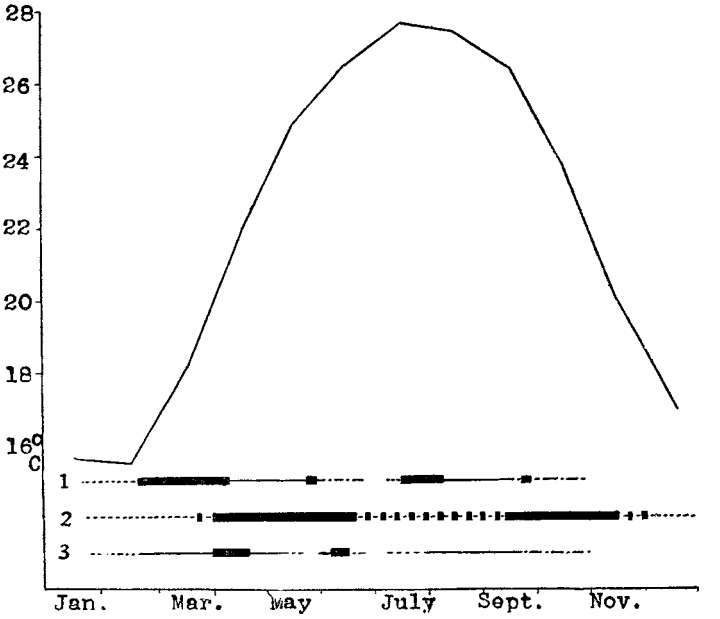


Fig. 30. The mode of prevalence of the subtropical type which is controlled by the complex of the factors (An example at Taichung, 24°09' N).

..... Seed - bed stage; ——— Vegetative stage in paddy field; -.-.-. Heading & maturity stage; ▬▬ Duration of prevalence in the higher degree; ▬ ▬ ▬ ▬ Duration of prevalence in the lower degree.

(1) Duration of host susceptibility (2) Possible duration of prevalence (so far as temperature is concerned) (3) Duration of natural prevalence Month

D. Characteristics of the Rice Blast Disease in the Tropics

The above - mentioned controlling factors are arranged, as shown in the following table, according to the relation of them to the host and the parasite.

Table 130. Grouping of the controlling factors of prevalence

Type of prevalence	Number of factors related to		
	Host	Parasite	Total
The temperate type	0	1	1
The subtemperate type	1	1	2
The subtropical type	3	1	4
The tropical type	2	0	2

In view of the data given in the table 130, it is clear that the prevalence of the temperate and the subtemperate type is constituted chiefly by the factors related to the growth of the parasite, whereas that of the subtropical and the tropical is effected chiefly by those related to the resistance of the host. Such phenomena stated above are due to the facts that in the former the relation of the environmental conditions to the growth of the parasite is of major importance for the outbreak of the disease, since the growth of the parasite is possible only during a limited length of time throughout the year, but in the latter the resistance of the host has an important bearing upon the prevalence, as the temperature is warm enough for the propagation of the parasite all the year round.

E. A Criticism on the Control Measures of the Blast Disease in the Tropics

Ito (1932, *et passim*) considered the prevention of the primary outbreak as the most important method of control of the present disease and proposed the all-round control measure (the so-called "common treatment") which proved very efficacious for the prevention of the present disease in the northern districts of Japan. Nevertheless, this method of control is not always effective in some other districts which are very different in the climatic conditions. As has already been stated by Ito himself (1939) when he visited this southern island, the control scheme should be established in accordance with the specificity in the respective districts. In the subtropical regions, the so-called "primary outbreak" is hardly recognizable, since the hibernation of the dormant fungus borne in the seeds and straws is not the only means of carrying over the disease to the following crop. In Formosa, the disinfection of seeds and the treatment of straws were extensively carried out under compulsion in the first crop extending over 3 years from 1942 to 1944, but the results of them were not satisfactory. This might be chiefly due to the natural infection caused by the fresh conidia born on the secondary tillers emerged from the stubbles, those on the seedlings derived from the gleanings, and the conidia

scattered on the ground, and partly by the dormant fungus surviving in the remains of the plants which were not treated properly. Ikata *et al.* (1938) pointed out that even in the isolated paddy field in the mountainous region of Pref. Okayama (ca. 34° 40' N), Japan, the prevalence occurs year by year in spite of the complete treatment of seeds as well as straws. This fact suggests that the infection is due to the conidia overwintered in the grass. As stated above, the prevalence occurs year by year without dormant conidia in the remains of the host plants even under the subtemperate condition, much more under the subtropical and tropical conditions. For these reasons, the control measures available for the tropical rice crop should be reconsidered from different angles, especially from the point of host resistance.

In subtropical and tropical regions, it is therefore desirable that the temperate varieties accomodated to the tropical conditions, e. g. "Horai" varieties, are further improved to become more resistant to the disease, especially to the leaf - blast, and at the same time the increase of resistance of some tropical varieties (the so - called "Indica" type) to the disease of ears and nodes of culms is taken into consideration, since a considerable number of the latter are susceptible to the disease of those parts, though most of them are quite resistant to leaf - blast. In this connection, it may be worthwhile to review breifly the history of breeding and distribution of "Horai" varieties in Formosa.※

(1) The 1st period (The period of distribution of the Japanese endemic varieties, 1903 - 1925). Since the introduction of the Japanese lowland varieties, the epidemic which had not formerly been recognized in this island occurred year by year, especially in 1926. In this year, the variety "Nakamura" which had been extensively raised owing to its resistance was severely affected in the lst crop season.

(2) The 2nd period (The period of selection of the resistant lines among the Japanese endemic varieties, 1926 - 1930). The pure lines

※For this history, the author was greatly indebted to Dr. Iso, especially to his book, "Lectures on the culture and breeding of ricc in Taiwan (1944)".

selected among the Japanese varieties, such as, Shinriki, Asahi, Iyosengoku, etc., were widely distributed under the name. Taichu Sp. No.2, Taichu Sp. No.6, Kagi - ban No.2, etc., respectively. The selction of these lines was chiefly made for the purpose of increasing resistance of the leaves to the disease.

(3) The 3rd period (The period of breeding by means of crossing within the Japanese endemic varieties, 1931 - 1933). Taichu No.65, the most widely distributed variety was bred in this period by crossing "Kameji" with "Shinriki", the female parent (Kemeji) being one of the well known resistant varieties in Japan.

(4) The 4th period (The period of breeding by means of crossing within "Horai" varieties, 1934 - 1946). Most of the important varieties in this period were bred by means of hybridization within the "Horai" varieties which had been bred during the 3rd period. The varieties bred in this period are considerably resistant in comparison with those of the foregoing periods, though they are not strong enough to stand against the excess of nitrogen or other unfavourable conditions.

Then, the next problem is to increase the resistance of the "Horai" varieties to the extent of that of the tropical varieties, or still higher if possible, by introducing the genes of the latter to the former. Although such a method of breeding has already been suggested by some Japanese authorities (Nakatomi, 1926 Terao & Midusima, 1930), the resultant data hitherto published are extremely few, so far as the author is aware. In this connection, the work of Iwatsuki (1942) may be worthy to be mentioned here. This Japanese workers succeeded to breed a limited number of hybrids by means of crossing between the Japanese lowland varieties and the upland ones, some of the latter are very resistant and generally considered as those introduced from China. Under the Formosan climatic conditions, however, these hybrids, *i. e.*, "Shinju No.1 and No.2", and "Futaba", failed to exhibit any distinct difference in resistance in comparison with the "Horai" varieties which are moderately susceptible according to the standardization made by the present author (*vid.* chapt. VI. Table 74). It was confirmed by the author by means of hybridization

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between the temperate and tropical varieties that the inheritance of resistance of rice to the blast disease is governed by two dominant factors. For this reason, breeding of the resistant varieties against the leaf-neck, and node-blast may be accomplished without much difficulty by means of crossing between the susceptible and resistant varieties. As has already been stated (chapt. VII, section 4), most of the selections which were resulted from the crosses between the tropical varieties and the "Horai" ones showed the higher degree of resistance, especially in the leaves, in comparison with the resistant "Horai" varieties.

In the course of breeding by this method, however, breeders often experienced to encounter many difficulties, for instance, high sterility, appearance of undesirable quality, retarding of heading and maturity, and other growth habits unsuitable for the mode of cultivation in the respective districts. Since the pioneer work of Kato *et al.* (1930) concerning the hybridization problem was published, the additional data on the increase of sterility in the crosses between the distantly-related types of varieties, i. e., "Japonica" and "Indica", have been reported by other workers, such as Johns (1930), Ohryoji (1941) and others. Nevertheless, according to Terao & Midusima (1939, 1942) and Ohkura *et al.* (1946), this phenomenon can not be so simply explained, being considerably different according to certain variety-groups. More recently, Oka (1947) pointed out that the sexual affinity between the individual varieties is very complicated *inter se* and the general tendency among the variety-groups classified according to the habitats is hardly recognizable. Such a contradiction in those studies is considered to be chiefly due to the difference of varieties employed. On the other hand, however, this fact may give us a hint that there is a possibility of breeding the fertile lines by means of crossing between the different types of varieties which are mutually congenial. For instance, as has been stated, this was partly realized by the crossing made by the present author in the experiments on the inheritance of resistance (chept. VI, section 5) and also on the resistance of the selected lines as well as the varieties bred from the practical point of view (chapt. VII, section 4). Other defects which may appear in the descendants can be more easily

eliminated by means of pure line selection. Thus, in future, the "Horai" rice, which name was primarily used for the Japanese lowland varieties either accomodated to the Formosan condition or bred in this island by crossing within them, may become those consisted of many types of varieties which are phylogeneticaly different from thsoe of the Japanese lowland type. Indeed, only through such a process of breeding, the resistance of "Horai" varieties shall be further increased in future. Furthermore, this method of breeding should also be applied to the improvement of varieties in the temperate regions, especially in Japan, where the increase of heritable resistance of the cultivated varieties has been very gradual and has never been attained at a jump in spite of the extensive studies made in the past half century because of the fact that the breeding was made merely by means of hybridization within the nearly related varieties.

In carrying out this kind of work, however, we must attend to the question regarding the change of varietal resistance induced by some environmental conditions as well as by the difference of the races on the part of the parasite. Concerning the variation in varietal resistance of the Japanese lowland rice under different environmental conditions, Ikata *et al.* (1931) pointed out that most of the resistant varieties native to the northern Japan become susceptible to the neck - blast when they are cultured in the southern Japan. Yasuda (1942) also reported that in the middle part of Japan the order of the grade of neck - blast resistance among several varieties employed was reversible when they were raised either in the mountains or in the plains. According to Bokura (1934), the fact that the neck - blast resistance of certain varieties except highly resistant ones is somewhat variable when grown in different localities, is due to the difference in time of heading during which the plants are blasted if temperature is favourable for the fungus. These phenomena may be regarded either as the so - called "disease escaping" due to the difference in growth duration of each variety or as those due to the physiological change of resistance effected by the environmental conditions. Then, the question arises as to whether or not such a phenomenon often occurs under the subtropical and tropical conditions. In this connection, the author (unpub-

lished) has already confirmed, working with the "Horai" varieties, that the annual and local variations in varietal resistance are quite small, especially in the resistant varieties, so far as the Formosan conditions are concerned, although in a few varieties the order of the varietal resistance judged from the annual mode of variation was somewhat different from that determined by the local average chiefly due to the difference of resistance of the parts of the plants, i. e., leaves, ears, nodes of culms, etc. This survey was made on the varieties which are more susceptible then those extensively grown in this island now. All the plants were grown at different localities with an excess of nitrogen in the 1st crop - season extending over several years, during which the weather was generally very unseasonable. It is therefore presumed that the varieties which are more resistant and normally manured ought to be more stable than the abovenamed. Moreover, it was also evidenced experimentally by the present author that the resistance of the varieties indigeneous to the tropics are more stabilized than those native to the temperate regions against different environmental factors, such as, air temperature, soil moisture and nitrogen supply (*vide.* chapt. VI, section 4). Thus, the selected lines resulted from the crosses between the temperate and tropical varieties may also be of value to meet the requirement pertaining to the stability of the tropical rice - crop. As for the specialization of the fungi parasitic to the rice plant, studies have becn extensively made by many workers, as known by those *Piricularia oryzae*, *Ophiobolus Miyabeanus*, *Gibberella Fujikuroi*, *Corticium* (*Hypochnus*) *Sasakii*, *Cercospora oryzae*, etc., but the experimental data regarding the appearance of the new pathogenic races in association with the newly bred resistant varieties have been very limited except for those given by Ryker *et al.* (1948) on *Cercospora oryzae* in Louisiana, Sasaki (1922, 1923) on the present fungus in Shikoku, etc. In Formosa, the author also confirmed the specialization of this fungus occurring in the artificial culture- and field conditions. Nevertheless, in considering the studies made in Japan as well as the present author's, the grade of specialization in pathogenicity of this fungus may not be so conspicuous as evidenced in the cereal rusts. Accordingly, in the rice plant

the stability of the cross - bred resistant varieties is considered to be higher then in wheat and other cereals. This presumption was further endorsed by the field tests conducted in the different districts of Formosa extending over so many years as already mentioned.

F. Conclusion

From the results stated above, the following conclusion can be drawn. The prevalence of the rice blast disease is conditioned by the following four factors.

(a) Relation of temperature to the growth of the fungus.

(b) Relation of temperature to the resistance of the rice plants.

(c) Relation of age of rice plants to the resistance.

(d) Inherent resistance of the cultivated varieties.

In combination with the above - named factors, the prevalence is classified into the following four types.

(1) The temperate type (controlled by the factor a).

(2) The subtemperate tvpe (controlled by the factors a and c).

(3) The subtropical type (controlled by the factors a, b, c and d).

(4) The tropical type (controlled by the factors c and d).

As stated above, the prevalence in the temperate region is entirely controlled by a single factor which is directly related to the growth of the parasite, and that in the subtemperate is chiefly conditioned by one more factor, *i. e.* age difference, whereas in the subtropical and tropical regions the prevalence is chiefly and wholly controlled by the factors relating to the hosts, respectively. Accordingly, the method of control in the temperate and subtemperate regions should depend upon the prevention of the fungous growth, while in the latters a stress should be laid on the increase of the host resistance, the most effective method being the increase of the inherent resistance of the varieties. In all probability this may be accomplished by introducing the resistant genes of the tropical varieties to the temperate ones.

Summary

(1) In the present experiments, studies were made on the factors conditioning the prevalence of rice blast disease, in order to find out the fundamental principle of control of the disease in the tropics.

(2) Temperature is quite important as a controlling factor of prevalence, especially in the temperate zone, since the temperature condition favourable for the parasite (*i. e.* 20 - 32°C, especially 26 -28°C) and host is limited to a rather short period.

(3) The resistance of the host is enhanced in proportion to the increase of air- and soil temperature at which they are grown, since at the lower temperatures there is an accumulation of nitrogenous compounds in the plant, while at the higher temperatures N-content is decreased but silicic accumulation is increased. In the temperate regions, the disease is very prevalent due to the decrease of resistance induced by cool weather, notwithstanding that the temperature of most rice-crop season is lower than the optimum for the fungus. On the other hand, in the tropical rice-crop as well as in the 2nd crop of the subtropics, the disease is not so serious because of the fact that the host resistance is intensified by warm weather in spite of constant propagation of the parasite.

(4) The rice leaves are susceptible during a seedling - and tillering stage, but become resistant towards the last tillering stage and maintain higher resistance during the stage from heading to maturity. The necks of ears also increase their resistance in proportion to the lapse of time after heading. These relations are correlated with the change of anatomical and chemical characters. The fact that the prevalence in the subtemperete, subtropical and tropical regions occurs only at the later seed-bed stage, the tillering stage and maturity is directly related to the age-difference of the plants and not due to the temperature condition, since in these regions the temperature during the rice-crop seasons is generally

favourable for the growth of the parasite.

(5)The varieties native to the temperate regions are congenitally susceptible to leaf - blast, but most of the varieties endemic to the tropical regions are quite resistant to it. As to the resistance of necks of ears as well as nodes of culms this tendency is not so clearly recognizable, though the tropical group includes resistant varieties greater in number than the temperate. Moreover, the resistance of the tropical varieties is hardly effected by the environmental conditions, such as air temperature, fertilization, soil moisture, etc. The inheritance of varietal resistance to the leaf-, neck - and node - blast is governed by the two dominant factors which confer resistance. The heritable resistance is an important factor for controlling the prevalence. The phenomenon that the serious prevalence is limited to the temperate Asia and has not been reported from tropical Asia is chiefly due to the susceptibility and resistance of the varieties native to the respective region.

(6) So far as the subtropical field conditions are concerned, the prevention of the primary outbreak, and that of the invasion of the host by the fungus by means of spraying with fungicides and removal of the dew drops from the leaves, is not accomplished so effectively, though the artificial promotion of host resistance by means of chemicals applied to the soil is more or less evidenced. Whereas the pure lines selected among the descendants resulted from the crossing between the temperate and tropical varieties showed a remarkable resistance, especially to leaf-blast, in comparison with the resistant "Horai" varieties. Therefore, the cultivation of the resistant varieties bred by the above- named processes is considered to be most efficacious for the control of the prevalence under the subtropical and tropical conditions.

(7) Considering the results mentioned above, the prevalence of the present disease is largely conditioned by the following four factors: (a) Relation of temperature to the growth of the blast fungus; (b) relation of temperature to the resistance of the rice plant; (c) relation of age of rice plants to the resistance; (d) the inherent resistance of the varieties. The prevalence in the different climatic regions is divided into the temperate--,

subtemperate--, subtropical-- and tropical type, and these types are chiefly governed by the factor (a); (a) and (c); (a) (b) (c) and (d); and (c) and (d), respectively. In other words, the prevalence in the temperate region is entirely controlled by a single factor which is related to the growth of the parasite *per se*, while in the subtemperate the prevalence is conditioned by one more factor, *i. e.* age-difference. On the other hand, in the subtropical and tropical regions the prevalence is governed mostly by the factors relating to the resistance of the host. Accordingly, in the two first-named regions the prevention of the fungous growth is of major importance for the control of the disease, while in the remainders the increase of the host resistance is primarily important. For the latter purpose it is advisable to increase the resistance of the host plant by crossing.

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